From the Division for Anaesthesia and Intensive Care
Department of Clinical Science,
Intervention and Technology
Karolinska Institutet, Stockholm, Sweden

TEAMWORK TRAINING USING PATIENT SIMULATION

Lisbet Meurling

Stockholm 2013

Cover page illustrating Simulation Based Team Training (SBTT) Photo:Rickard Kilström

Published by Karolinska Institutet.

ISBN 978-91-7549-159-2

Printed by
REPROPRINT AB
Stockholm 2013
www.reproprint.se
Gårdsvägen 4, 169 70 Solna

Not everything that can be counted counts,
and not everything that counts can be counted.

Albert Einstein

To my family

ABSTRACT

Teamwork is an important factor in safe healthcare. Simulation based team training (SBTT) is a method to gain the non-technical skills important for proficient teamwork. This thesis evaluated SBTT using different modalities and evaluation levels, looking at *whole* teams of either medical students or full professionals.

In study I 15 medical students participated in a target-focused scenario-based teamwork practice during a one-day course. Their team behaviour skills were video-recorded and their attitudes towards safe teamwork assessed in this observational cohort study. Team behaviour skills showed improvement after five scenarios in a full-scale patient simulator environment, while no change in attitudes toward safe teamwork were detected.

In study II 54 medical students participated in three video-recorded scenarios (n=36). Clinical performance improved in one variable; the frequency of sum-ups. Changes in individual experiences could be detected early during SBTT; self-efficacy improved after training. Individual teamwork behaviours did not change after this half-day course. Participants communicated to a greater extent and experienced higher mental strain and concentration in the role of leader than in the role of follower.

Study III investigated whether training with high-fidelity simulators (HFS) could increase trainees' experience of realism in task performance and facilitate the trainers' task, resulting in different behaviour and individual experiences than training with low-fidelity models (LFM). A case control study was conducted with 34 teams using either a LFM (n=17) or a HFS (n=17). Professionals involved in paediatric emergencies performed one video-recorded emergency scenario *in situ* in an authentic emergency room. The trainees' time to deliver oxygen was significantly longer (p=0.014) when using a HFS, which was interpreted as more realistic timing of task performance. Leaders experienced a higher level of mental strain during training with a HFS. There was a reduction in the trainers' frequency of interventions in the scenarios as well as their mental strain, signifying potential for the trainers to focus more on trainees' behaviours and performance during training using a HFS.

In study IV all staff members (n=152) in an intensive care unit (ICU) were trained during one day. An observational cohort study (case control design on sick leave and staff turnover) was conducted. The training was performed *in situ* at the ICU and preceded by an interactive lecture concerning human factors. Before training, the medical professions' perceptions of safety differed. After the training period, nurses' and physicians' mean self-efficacy scores improved, and nurse assistants' perceived that the quality of collaboration and communication with physician specialists improved. In addition, nurse assistants' perception of the Safety Attitude Questionnaire (SAQ) factors teamwork climate, safety climate and working conditions were more positive after the project and in concert with nurses' perception of safety climate. In comparison to a control ICU during the study period, the number of nurses quitting their job and nurse assistants' time on sick leave was reduced.

In conclusion, the SBTT protocols applied in these studies are promising. A one-day course seems to benefit medical students' teamwork behaviour. During a half-day course, i.e. early phase of training, aspects of clinical performance were improved as well as self-efficacy. Equipment fidelity influenced trainees' clinical performance to some extent, but the trainers' performance and experience to a larger extent. Leaders, followers and the different medical professions reported different experiences and attitudes. This finding accords with earlier studies on professions but has not been well studied earlier in the context of leaders and followers. All professions benefited from one day of SBTT in an ICU, but it was expressed in different ways.

LIST OF PUBLICATIONS

This thesis is based on the following papers:

I. Wallin C-J, Meurling L, Hedman L, Hedegård J, Felländer-Tsai L. *Target-focused medical emergency team training using a human patient simulator: effects on behaviour and attitude*. Med Educ 2007;41(2):173–80 doi:10.1111/j.1365-2929.2006.02670

II. Meurling L, Hedman L, Felländer-Tsai L, Wallin C-J. *Leaders´ and followers´ individual experiences during early phase of simulation-based team training; an exploratory study.* BMJ Qual. Saf Published on line first: (3 January 2013) 10.1136/bmjqs-2012-000949

III. Meurling L, Hedman L, Lidefelt K-J, Escher C, Felländer-Tsai L, Wallin C-J**.** *High-fidelity paediatric simulation team training makes a difference: A case control study. Manuscript*

IV. Meurling L, Hedman L, Sandahl C, Felländer-Tsai L, Wallin,C-J. *Systematic simulation-based team training in a Swedish ICU - a diverse response among critical care professions.* BMJ Qual. Saf. Published on line first: (14 February 2013) doi:10.1136/bmjqs-2012-000994

CONTENTS

LIST OF ABBREVIATIONS

CRM	crew resource management
ANTS	anaesthetists' non-technical skills
EMCRM	emergency medicine crisis resources management
OTAS	observational teamwork assessment for surgery
A-TEAM	all team members' behaviour scale/program
ICU	intensive care unit
ER	emergency room
SAQ	Safety Attitudes Questionnaire
FMAQ	Flight Management Attitude Questionnaire
SBTT	simulation based team training
OTRMS	operating team resource management survey
CAMST	Center for Advanced Medical Simulation and Training
GEE	generalized estimating equations
LFM	low fidelity model
HFS	high fidelity simulator
ANOVA	analysis of variance
IQR	inter quartile range
CI	confidence interval

1 BACKGROUND

Patients, relatives and staff involved in health care expect the care delivered to be safe and of high quality. Worldwide reports of large, significant rates of health care errors caused by human factors have generated a discussion about how to identify the causes of errors, avoid them and improve care.[1-7] A recent study even argues for strategies giving hospitals stronger financial incentives to avoid complications.[8] The discussion in health care has turned from individuals' guilt for a given error to scrutinizing systems and teams and from focusing only on technical skills to including non-technical skills.[9] This shift occurred earlier in the airline, military, and nuclear power industries where among other actions non-technical skills have been taught for decades. Non-technical skills refer to "the cognitive, social and personal resource skills that complement technical skills, and contribute to safe and efficient task performance".[10]

The book *To Err is Human* acted as an early alarm in health care.[11] Communication breakdowns, poor team coordination and procedural errors were among the first observed problems.[12] The last decades the volume of literature on how to deliver excellence in non-technical skills in health care has expanded. Health care work is complex and requires coordination among all the professions involved; moreover, teamwork has been recognized as an important factor for patient safety.[13] Teams in health care, especially in intensive care, emergency medicine, trauma and resuscitation, work under conditions that change frequently; these teams might be assembled ad hoc, have dynamically changing team membership, work together for a short time and have to integrate different professionals' cultures.[13] In emergency situations staff members encounter moments when life and death is at stake and they must collaborate and coordinate with people they maybe not even know. Team performance competencies can be categorized as knowledge (cognition, "think"), skills (behaviour, "do") and attitudes (affect, "feel").[14] Knowledge can be gained, teamwork behaviour changed and attitudes influenced.[15-17] Practice makes perfect, but who will be practiced upon?

It is possible to avoid training (practice) on patients, at least in the early phase of the learning curve. Other training methods such as training in skills stations, simulators and computers have been used with promising results for individual and team performance.[15, 18-27] Patient simulators can be applied for several kinds of team training for example: neonatal or adult resuscitation, implementation of checklists, crisis management skills during operations and improving handoff communication.[18, 28-33] Aggarvall et al evaluated simulation with regard to the seven key competencies CanMEDs framework required for physicians to provide high quality care.[34] They concluded" It has been shown that simulation can already promote the competencies of medical expert, communicator and collaborator; however, further work is required to develop the exact role of simulation as a training mechanism for scholarly skills, professionalism, management and health advocacy". A meta-analysis of 21 studies on different types of organizations concluded that systematic team training works and is positively related to team effectiveness in five outcomes: affective, cognitive, subjective task-based skills, objective task-based skills and teamwork skills. The largest effect occurred on cognitive outcomes.[21] Studies using various team training strategies have shown that they can improve the effectiveness of multidisciplinary acute care.[19]
A number of techniques can identify the specific non-technical skills important for safe, efficient team work in each clinical area.[10] However, when studying different taxonomies, it is obvious that many basic skills are generic, such as decision-making, situation awareness, communication, teamwork, leadership and stress/fatigue

management.[10] In a recent interview study, experienced anaesthesia nurses gave their description of how excellent anaesthetists perform; all aspects expressed were non-technical skills, and the authors concluded that these aspects attract too little during the specialist training.[35] Optimal teamwork behaviour exhibiting proficiency at non-technical skills is not inherent; professionals must be taught how to act, reflect and then practice these skills. Therefore, different authorities in health care recommend implementation of team training.[36]

Salas et al. already ten years ago reviewed the literature and concluded that team training works but depends on a well-designed curriculum and support and reinforcement from the organization.[15] Skill decay has been studied but the results are inconsistent, depending on the specific skill acquired, the degree of skill learning and the time between learning and follow-up.[37-39]

Interventions focusing on teamwork have shown a relationship with improved teamwork and safety climate.[17, 40, 41] The literature on the safety culture and climate and the number of studies indicating a positive correlation with patient outcome are growing, but a direct impact on patient outcome from a single intervention is hard to prove in the multi-factorial environment of health care.[42] Thus the safety culture at work is also of interest to assess and maybe impact.

Research on training with patient simulators has increased during the past two decades, but questions remain to be answered.

Photo 1. Instructors from CAMST preparing for in-situ simulation based team training (SBTT)in ICU at Karolinska University Hospital, Huddinge.

1.1 TEAMWORK TRAINING

What is a team? According to Salas et al, a team is "a distinguishable set of two or more people who interact, dynamically, interdependently and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have limited life-span membership".[43]

1.1.1 Leadership and followership

All team members, both leaders and followers, are involved in executing tasks to achieve the desired goal: to solve the situation in the patients' best interest. Leading and following are collaborative adaptive behaviours, an evolutionary strategy for solving coordination problems.[44] There is no leader without a follower, and both need to support the mutual role assignment to maintain the integrity of the team structure and process.[36] In health care the entire staff has to be able to act as a leader or a follower according to the demands of the situation. Due to a specific profession or competence some persons might most often take the leader role and some nearly always the follower role. When leaders and followers shift roles, shared leadership might evolve.[45] Evenly distribution of leadership among team members has a positive association with better performance and results.[46, 47] Cross-training, or practitioners of different professions or experience levels changing positions during training, has been advocated to increase the understanding of other's roles.[14] For example teammates switch responsibilities and coordination requirements in order to improve the teams' anticipatory behaviour and foster communication and coordination strategies.

Since the competences of roles differ their learning process or needs might not be the same. The literature looking at leaders and followers attitudes and behaviours separately during team training is scarce.

1.1.2 Training method

A number of basic sources can aid in the design, implementation and assessment of training and learning.[10, 15, 37, 48-51] Participants and their training needs should be defined before training, and the training should have explicitly stated learning objectives for medical goals, clinical performance and individual teamwork behaviours. Training ideally utilises information-based (seminars), demonstration-based (behavioural modelling) and practice-based (simulation) methods. Experienced, educated trainers should deliver the training and trainees should receive individual feedback. It is of utmost importance that participants' needs, training objectives, method used and the assessment be coordinated, i.e., be in constructive alignment.[48] Repetitive practise is commonly advocated and requires much effort and resources from the management to organize.[52, 53]

The trainers' education and approach are of great importance.[54] The literature can provide a solid base of knowledge, but the skill to perform a training session, deliver high-quality feedback and catch the critical moments has to be practiced with support. Trainers have to treat trainees humbly and with respect and always, whatever the levels of the trainees' performance, instruct them or facilitate their growth in their task and self-efficacy. These skills are of crucial importance; it is easy to purchase a simulator, but use of that equipment carries a huge amount of responsibility. It is a powerful tool which requires knowledgeable, experienced trainers to avoid negative effects from training, such as unwanted simulator behaviour that could have harmful effects if transferred to the authentic clinical situation.

1.1.3 Crew resource management

One of the most commonly used training strategies for non-technical skills is crew resource management (CRM).[10, 55] In aviation failures have been attributed more often to human errors than mechanical ones since the technical development and introduction of the highly reliable turbo-jet aircraft in the late 1950s.[56] Consequently training changed to address not only technical proficiency but also team issues. CRM has been shown to change attitudes and observable behaviour and has been associated with decreased surgical morbidity.[56, 57] CRM has been adapted to medicine and its use has become widespread. The current generation of CRM holds an underlying assumption that human errors are inevitable, thus organizations must recognise and accept this fact.[10] According to Flin et al., the core concept in CRM training is not to strengthen a specific team but to make individuals more effective at working with any team.[10] In the clinical context this skill entails the ability to work effectively in an acute situation with strangers or those with whom one does not get well along with toward one common goal—the patients' outcome.

1.1.4 Assessment of training

Assessment of the training is important for various reasons. Management wants value for the money, trainers need feed-back on their work, trainees want to know if they reached their goals in training and above all we want to track improvements in our daily work in health care. There are different frameworks for assessment of training. Assessment can focus on individuals or teams, trainees or trainers, the different roles of trainees and professional groups. Furthermore, assessment can look at various levels of knowledge, skills and or attitudes.[58] Kirkpatrick' four level model of training evaluation has been used in education and training for a long time and was recently adapted for higher education.[59, 60] The four levels of this model are reaction, learning, behaviour and results.[59] Reaction, level I, deals with trainees' immediate reaction to a training session, such as their affective reactions and opinions about its usefulness. Learning, level II, refers to direct measurements of learning outcomes during training, such as tested knowledge or observed behaviours. Behaviour, level III, encompasses the transfer of knowledge, skills, and attitudes from the training to the workplace. Results, level IV, concerns changes in trainees' knowledge, skills and attitudes detectable in the working place, such as improved patient outcomes, staff well-being or organizational profit.

1.1.5 Assessment of non-technical skills

It is of great importance to address assessment of non-technical skills in team training in order to give formative and summative feedback and evaluate whether the training is effective. The rating instruments used to assess trainees or students during task performance must be robust and easy to understand and use. Raters should be trained to use them correctly. Assessment is preferably both formative and summative. Formative assessment improves learning and encourages reflection on the goals for the training, while summative assessment evaluates whether trainees have reached the specified goals after the training. Different rating systems are designed for different purposes, possess their own psychometric properties, are not static and have to be refined in response to changed environmental conditions.[10] Examples of behaviour rating systems for evaluating non-technical skills in health care include ANTS Anaesthetists' Non-technical Skills (ANTS), Non-technical Skills for Surgeons (NOTSS), Emergency Medicine Crisis Resources Management (EMCRM) and Observational Teamwork Assessment for Surgery (OTAS).[61-64]

1.1.6 A-TEAM program

In order to align the targets with the training and with both formative and summative assessment and given with the need to not tax limited working memory, the A-TEAM program was designed and used in study II and III.[36, 65] The A-TEAM program is based on a structured decision-making strategy drawing from earlier research, figure 1.[36] The program has not yet been validated.

Figure 1: A schematic presentation of a structured team decision-making process.

The A-TEAM program is a tool for targets for training as well as observation and rating of all team members' behaviours. The five categories of behaviours are presented in Table 1 and the first (Takes a membership role) is further divided into three subcategories. The categories are assigned four grades with examples of behaviour elements; poor, in need of improvement, good and proficient. All grades are used in formative and summative assessment, but only the "good" and "proficient" grades are used as targets for training. Each element in the grade refers to directly observable behaviours in order to exclude assumptions by the observers and raters. The numbers of elements are limited to make the program easier for the observer to use without much practice. When used for research, the data should be treated as binary data; thus all data are converged to two stages: 0=poor and in need of considerable improvement, 1=good and proficient.

Table 2: The-A TEAM scale for assessment of individual team behaviour

1. Take a team member role			
All team members' behaviour			
A team member participates actively in all relevant aspects of teamwork and task work, observes other team members' performance and activities, and provides and accepts feedback and assistance.			
Poor	In need of improvement	Good	Proficient
Does not give or welcome any support. Does not acknowledge other members. Work on his/her own. Does not give or take advice gracefully.	Support others only if challenged, not spontaneously. Supports in a reluctant way.	Supports others, e.g. by helping when obviously needed.	Accepts and gives support directly. Acknowledges and involves others frequently. Asks quickly for help when needed. Protests clearly against inaccuracies.
Leader behaviour			
A team leader takes initiative to provide structure and direct teamand task work.			
Poor	In need of improvement	Good	Proficient
Does not identify himself/herself as person in charge of the situation. Makes no final decisions. Tries to 'do it all'. Does not take initiatives.	Tries to make decisions and give orders but very unclear and vague. Takes initiative, but not in time when needed.	Makes decisions, but not clear enough. Gives orders, but not directed.	Makes final decisions. Gives clear orders. Takes initiatives to e.g. short briefings; confirms and verbalizes decisions. Accepts a non-leading role when appropriate.
Follower behaviour			
A team follower supports the leader's initiatives, and assumes assigned responsibilities and directives.			
Poor	In need of improvement	Good	Proficient
Challenges the leader in an obstructive way Stands back, takes a 'hands-off approach'. Demonstratively does not participate in briefings	Performs task duties, but only on demand. Does not support the leader verbally or in other ways.	Supports the leader both verbally and in other ways. Takes a 'hands-on approach'	Supports the leader. Takes a 'hands on' approach. Challenges constructively. Requests and participates actively in briefings. Takes over leadership if required.
2. Gather information and communicates			
All team members actively gather and exchange information.			
Poor	In need of improvement	Good	Proficient
Does not communicate at all. Masters through oral or body language. Engages in unnecessary conversation. Makes inappropriate comments.	Communicates vaguely, quietly or continuously without pause.	Communicates in round terms, but not aimed at a team member. Does not give feedback.	Communicates in round terms. Uses closed-loop communication. Uses SBAR format for briefings. Calls out critical information during emergent events. Makes good eye contact. Uses team members' names.

3. Contributes to a shared understanding of the situation.			
In collaboration, all team members develop and maintain a common understanding of the situation, and have team situational awareness.			
Poor	In need of Improvement	Good	Proficient
Does not share any information. Demonstratively does not contribute.	Reports findings unclearly. Gets distracted by non-essentials. Acts independently on symptoms without confirming with others. Does not try to explain things to others when obviously needed to.	Reports findings (positive and negative) in a clear and concise way.	Interprets information in a timely manner. Shares information and explains core events, thus making them understandable to the whole team.

4. Makes collaborative decisions			
In collaboration, all team members consider options, resources and risks to able to take decisions.			
Poor	In need of Improvement	Good	Proficient
Defies any attempts to decision and does not state an alternative. Demonstratively does not take part.	Makes decision right away without discussing alternatives with the team though time and opportunity exists.	Contributes with ideas, but does not state any own opinion.	Re-evaluates, discusses and takes other alternatives in consideration with other team members before reaching a conclusion. Actively drives the decision process forward.

5. Coordinates and executes tasks			
A team member coordinates his/her tasks in a timely and integrated manner with other team members\ activities, facilitating the performance of other members\ jobs.			
Poor	In need of Improvement	Good	Proficient
Does not coordinate at all. Acts on his/her own. Stops others. Carries out inappropriate courses of action. Does not adhere to	Obstructs but does not stop. Does not change plans despite new information.	Coordinates, but not for the whole team. Keep things progressing, but not in a clear and efficient way.	Coordinates his/her activities with others. Adapts to any changes in the present situation. Prioritizes tasks. Tells others of plan for further care. Adheres to guidelines

Figure 1 and Table 1 are reprinted by permission of the Publishers from ‘A Schematic Presentation of a Structured Team Decision-Making process’, in *Safer Surgery* eds. Rhona Flin and Lucy Mitchell (Farnham: Ashgate, 2009), p.133.

1.1.7 Simulations and fidelity

Simulations are commonly used for team training in health care but as all other forms of team training require a solid curriculum and resources.[50] In various degrees of realism a mannequin that mimics a patient is placed in a room equipped to resemble an emergency room (ER), operating theatre or other health care facility, e.g., or authentic ICU or ER. Simulations allow the trainer to control the learning environment and to pause the events during training. Simulation fidelity can be defined as equipment, environment and psychological fidelity, of which psychological fidelity is considered most important for training.[66] Psychological fidelity refers to the extent to which trainees perceive the simulation as a reliable substitute for the actual task.[66] To ensure equipment fidelity, high-fidelity simulators are increasingly popular but evidence to justify the higher costs compared to low-fidelity simulators is limited. Low-fidelity simulators are static and do not interact with the environment. In contrast high fidelity mannequins give computerised, physiological feedback in response to the participants' actions. The importance of equipment fidelity has been debated but no degree of fidelity replaces the importance of the training method.[66-69] Finan et al found no significant differences between neonatal low- and high-fidelity simulators in performance, non-technical skills, subjective stress or salivary cortisol in a recent study.[68] A comparison of three simulation-based methods by Owen et al. found advantages for full-mission simulations (high fidelity in a setting replicating an authentic clinical environment) over computer screen-based training and low-fidelity whole body simulators.[70] Full-mission simulation training improved the ability to transfer learned skills, especially behaviour and overall performance, from one type of emergency situation to another. These findings are a few examples of the inconclusive results in favour of either type of equipment fidelity; thus further study is warranted.
The location of training, either at a centre or *in situ*, has also been debated in the literature. Training *in situ*, that is at the actual workplace and not at a training centre, might reinforce the clinical behaviours and open up for opportunities to identify hazards and deficiencies.[71] Sometimes, on the other hand it might benefit training to get some distance between staff and the workplace conflicts and culture. *In situ* simulations require that the mannequin and other equipment such as cameras be mobile and transportable.

Photo 2: Instructor performing CPR on a patient simulator.
(*Photo: Rickard Kilström*)

1.2 INDIVIDUAL EXPERIENCES AND ATTITUDES

Individuals' personality, education, national culture, professional culture and workplace climate and culture are only some of the factors that shape our attitudes, beliefs and expectations. What comes first during training? Does a change in attitude or beliefs or the rehearsed behaviour during training create an experience and alter individuals' attitude? In the early phase of simulation-based team training, trainees often have highly positive reactions even when no other changes can be detected.[22, 72] These positive reactions are extremely important; otherwise it would be impossible to motivate further training. Each individual is one piece of the team and will be one piece of the emergency team in the next acute clinical situation they handle. It is unlikely that the composition of that emergency team will be the same as the team that trained together; thus each individual possess safe attitudes and behaviour.

In health care emergency situations present high stress levels, the consequences of each decision could be critical, there are often multiple simultaneous tasks with large fluctuations in demand and the stimuli are driven, not self-paced—all key elements in high workload tasks. While the extent to which any given individual can cope with the high workload is unknown, assessing the level of mental effort and providing techniques to help team members and lighten the workload are of utmost importance.
Individual experiences of the training as well as experienced communication and safety culture and climate, attitudes towards safety, teamwork and working conditions are thus of interest when assessing team-training. Attitudes are often assessed by questionnaires or interviews.

1.2.1 Self-efficacy

Perceived self-efficacy is among the factors that affect human motivation and refers to the belief in one's own capabilities to perform given actions.[73] Persons with high self-efficacy are more likely to make more effort in a specific task, sustain that effort and resist adversity longer than those with low self-efficacy.[73, 74] Self-efficacy is a prerequisite for learning and a predictor of intellectual performance. Practitioners must know the task demands; otherwise there will be a discrepancy between self-efficacy and performance.[73] In addition, to better act as a predictor of performance, the factor studied has to be targeted to people's belief in their capabilities to do what has to be done in any given situation, rather than their belief in only one isolated aspect of self-efficacy.[73] Simulation-based training can improve both individual and team self-efficacy and is also an important individual factor in demonstration-based training, but there is still no consistent correlation with observed measures of competence and self-efficacy.[75, 76]

1.2.2 Mental strain

Researchers have created models to explain findings that multi-tasking decreases performance. Mental workload and multiple resource theories are two related concepts.[77] Of the three components related to demand, resource overlap, and allocation policy in Wicken's multiple resource model architecture, the concept of mental workload is most related to demand.[77] Workload can be characterized as a mental construct that reflects the mental effort or the mental and emotional strain (the excess mental effort induced by the anxiety-evoking cognitive aspects of a task) resulting from performing a task under certain environmental and operational conditions, coupled with the capability of the individual's limited mental resources to respond to those demands.

Definitions of mental workload will likely continue to be proposed and tested, and each research field will adopt its culturally preferred definition. Most definitions refer "to the portion of operator information processing capacity or resources that is actually required to meet system demands".[78]

There are an abundance of subjective methods to assess mental workload such as the NASA Task Load Index (NASA TLX) and the Instantaneous Self-Assessment of Workload (ISA).[79, 80] Since these methods are labour intensive, mental strain can be assessed more simply with the validated Borg Category Ratio scale (CR10), which is used frequently in studies on stress and arousal resulting from difficulty handling physical and mental load.[81]

1.2.3 Flow experience

Flow is a positive experience during training and of great interest and importance for teaching and learning. Flow is a subjective state in which people report the feeling of being totally occupied and concentrated on the work at hand, forgetting time and fatigue. This enjoyable state has also been described in risky activities, typically activities that offer at least a possibility of control.[82] According to Csikszentmihalyi et al., flow requires three key conditions to occur: a clear set of goals, a balance between perceived challenges and perceived skills and the presence of clear, immediate feedback. The experience of flow is a powerful motivating force that helps practitioners continue with activities that are not engaging at the start; thus, the feeling of flow yields emergent motivation. Flow is associated with scientific creativity, learning and teaching and is also related to skills development.[82] There is still no known optimal level of flow during simulation-based team training; however, knowledge in this area could be increased by comparing the level of flow in different settings, professions and team roles.

1.2.4 Experienced quality of collaboration and communication

The quality of teamwork and communication in particular has been found to be common contributory factors in adverse events.[13, 83-88] In the late 1980s Gaba discussed human error and, among other factors, identified communication failure in anaesthesia mistakes.[3] In one of the first publications investigating human errors in the ICU, Donchin et al. found an association between nurses' and physicians' communication and errors in the ICU.[89] According to Raeder et al., inputs important for ICU team communication are "group communication norms, the roles and status of team members, expertise required for performing a task, use of protocols for structuring communication, team communication strategies, interruptions, and group reflections on teamwork".[90] Health care teams are often hierarchical, both within (junior vs. senior) and among professions. The norms within each profession is exemplified by its senior members and passed on to junior members, creating a common strong bond of professional membership.[91] The experienced quality of collaboration differs among health care professions in studies; physicians generally report more positive collaboration than nurses.[92 93, 94 95, 96] It has been speculated that these differences might be due to different ways of communication taught during educational training and further influenced by differences in status and authority, patient care responsibilities and gender.[92, 93] These learned patterns of collaboration and communication and the different experiences are possible to address with team training and communication tools, with the ultimate goal of increased patient safety.

Implementation of multidisciplinary work-shift evaluations improved reported communication in ICUs.[97] In a successful, global population approach, the implementation of a surgical checklist designed to improve team communication and consistency of care was found to reduce morbidity and mortality.[16] Risk-adjusted morbidity was correlated with the estimated levels of communication and collaboration in surgical teams but not with the assessed levels of teamwork climate, safety climate or working conditions.[98] However, as with safety culture, the existing status at the unit must be assessed and interventions to target the needs need to be addressed. Among the questionnaires used to measure this issue, part of the Safety Attitudes Questionnaire (SAQ) has straightforward questions on the quality of collaboration and communication between the respondent and their own and other professions.

1.2.5 Safety culture

Health care's increased focus on safety issues has created interest in studying the safety culture as an indicator of both the existing status in the organization and the effect of implementations. Safety culture is viewed upon as faster in reflecting changes in processes and systems compared to outcome measures.[99] While specific definitions of safety culture vary, it broadly refers to the individual and group values, norms, attitudes, perceptions, competencies and behaviours within an organization and the structures and processes that support these elements.[99, 100] Safety climate is a subset of safety culture and refers to staff members' attitudes towards certain aspects of safety culture. These attitudes are more readily measurable through questionnaires than culture. The terms safety climate and culture are sometimes used interchangeably in health care.

Safety climate has been shown to be scored higher in hospitals with a group culture than a hierarchical culture but shows even more variability within than among hospitals.[94, 101] Physicians and nurses have different attitudes about teamwork according to a number of studies on ICUs and other areas.[92, 94, 96, 102 93, 103] In a study comparing medicine and aviation, medical staff was more likely to deny the effect of stress and fatigue than aviation staff.[104] Surgeons were also less likely to advocate flat hierarchies than ICU staff and cockpit crews, indicating differences among clinical professions. Open communication in ICU teams was found to be a predictor of understanding of patient care goals.[105] The authors emphasized the importance of leadership that promotes a flat hierarchy, that recognizes human fallibility and limitations and that clearly states expectations for team interaction patterns in order to create an atmosphere that encourages open communication.[105] Thus, the results of assessments of different aspects of safety culture are localised to the hospital, ward and profession.

Results that describe the association between patient outcome and the perception of teamwork and safety climate have been published and the number of studies is growing.[17, 106-109]Some studies indicate that perceptions of safety climate can be influenced and are associated with both patient and staff well-being and length of stay.[107, 109-116] Considering the literature, one fundamental question arises: What comes first, the hen or the egg, change in attitudes, behaviour or culture? In a report from The Health Foundation they argue for a change in view to a more complex interrelationship, with not only culture influencing behaviours and clinical outcomes, but also vice versa.[42]

There are a number of different questionnaires for assessment of safety culture and subsets. One of the most validated questionnaires is the Safety Attitudes

Questionnaire (SAQ), which comprises six subsets factors; teamwork climate, safety climate, job satisfaction, stress recognition, perceptions of management and perception of working conditions also comprising assertions about the experienced quality of collaboration and communication among professions.[100] The SAQ was based on the Flight Management Attitude Questionnaire (FMAQ), used to measure cockpit culture in commercial aviation. The questionnaire has been adapted for use in ICUs, operating theatres, general inpatient settings, emergency medical units, primary care and nursing homes. The Health Foundation compared different tools for measuring safety culture and found that while all had advantages and disadvantages, only the SAQ consistently established links with patient safety outcome supporting its extensive use in ICUs.[99] The SAQ has never been used in a Swedish ICU before but has been used at Swedish pharmacies.[117]

It has been discussed whether stress recognition should be a part of the SAQ.[101] The scores are hard to interpret not following the pattern of the other factors. The SAQ stress recognition results were excluded due to concerns about this domain's construct validity in a recent study.[106]

The choice of which of the well-established safety culture questionnaires to use might not be vital. It is important though that a unit or organization focuses on safety, regularly assessing the status of the unit and utilizing the results to generate open, responsive discussions and make targeted improvements.

1.3 STAFF WELL-BEING

Staff well-being is not only an important issue but also has significant implications. Throughout the world, health care organizations face challenges in recruiting and retaining health professionals; thus staff members' intent to stay is crucial.

In a paediatric ICU team communication improved and emotional exhaustion decreased after implementation of a multidisciplinary structured work-shift evaluation.[97] In a Finish study, physicians working in poorly functioning teams were at 1.8 times greater risk of taking long spells than if working in well functioning teams, this factor correlated to a larger extent than commonly reported sources of stress like overload for example.[118] The levels of safety climate and teamwork have been found to be positively associated with nurses' intent to stay.[119] An intervention program was implemented in a surgical unit with positive results in safety climate, teamwork climate and nurse turnover rates.[110] Caregiver interaction, a team-oriented culture, timely communication, effective coordination and collaborative, open problem solving were negatively associated with nurse turnover rates in a study of 42 ICUs.[120] Managers who provide a milieu that increase critical care nurses intent to stay practice a leadership style that values contributions from staff, promotes a climate in which information is shared, promotes decision making at nurse level, exerts position power, and influences coordination of work according to Boyle et al.[121] The perception of safety climate was not only associated with patient injuries but also with nurse injuries in a study by Taylor et al.[106] Overall, studies on staff wellbeing indicate a positive association with teamwork. Therefore, different factors influencing staff well-being are of interest in the assessment of the impact of teamwork training.

2 AIMS AND HYPOTHESES OF STUDIES I–IV

The overall aim of these studies was to explore some of the factors in the teamwork training process using patient simulators to improve teamwork outcomes and ultimately patient safety.

Aim study I: The aim of this study was to describe in detail a target-focused instructional strategy applied to a medical team and to evaluate the outcomes of this strategy in the team behaviour and attitudes of medical students.

Hypothesis study I: Teamwork skills and attitudes will improve in response to target-focused scenario-based teamwork practice during a one-day course.

Aim study II: The aim of this study was to explore individual experiences associated with medical students' learning and performance. Levels of mental strain and concentration (a subcomponent of the flow experience) in the roles of leader and follower were studied separately during the early phase of SBTT, as was the perceived pre- and post-training self-efficacy. Data was also sampled for the training outcomes: individual behaviours and team endeavour in clinical performance.

Hypothesis study II: Changes in individual experiences can be detected early during SBTT. Those in the roles of leaders and followers will have different responses.

Aim study III: The aim of this study was to study trainees' and trainers' performance, mental strain and flow experience during the training of professional teams using a low fidelity model (LFM) (control) or a high-fidelity patient simulator (HFS) (case) in an authentic ER In addition the trainees evaluation comments was registered in an exit questionnaire. Leaders and followers were studied separately for their mental strain and flow experience during training.

Hypothesis study III: Training with HFS will improve the experience of realism for trainees and support the trainers' task, resulting in different behaviour and individual experiences than training with LFMs.

Aim study IV: The primary aim of this study was to examine the relationship between SBTT in professional teams *in situ* in an ICU and different professions' self-efficacy, experienced quality of collaboration and communication, as well as perceptions teamwork climate, safety climate and participants' perception of working conditions. As a secondary aim, the influence of working conditions on changes in staff turnover and sick leave were examined.

Hypothesis study IV: SBTT of the entire ICU staff during a two-year period will improve individual self-efficacy and the perception of quality of collaboration and communication. Additionally, SBTT will improve the teamwork climate, safety climate and perception of working conditions in the ICU. Positive changes in staff turnover and sick leave will be detected.

3 MATERIAL AND METHODS

3.1 ETHICAL APPROVAL

Informed consent was obtained from all participants in all four studies.
Study I-II and IV: The institutional review board, Regionala etikprövningsnämnden i Stockholm, approved the studies, dnr 358/02, amendment 2007/1517-32.

Study III: The institutional review board, Regionala etikprövningsnämnden i Stockholm, approved the study, dnr 358/02, amendment 2007/1517-32 and 2010/0005-32.

3.2 STUDY DESIGN

Study I: Observational cohort study
Study II: Observational exploratory cohort study
Study III: Case-control study
Study IV: Observational cohort study (case control design for sick leave and staff turnover)

3.3 PARTICIPANTS AND LOGISTICS IN TRAINING

In studies I, II and III participants were given a personal code to label their scrub shirt during training and in studies I-IV to label their questionnaire for confidential data sampling.

For study I 15 medical students, 7 male and 8 female, 22 to 25 years old at the end of their fifth semester were recruited. All participants volunteered to participate and gave informed consent. They were remunerated with 100€ because the study occupied the students for one week during their vacation. Before the trauma training the students were prepared with 2 didactic lectures on trauma care, surgical and orthopaedic trauma because they lacked basic knowledge in this area. The participants took part in five training scenarios as active participants or observers. The participants had no earlier experience of team training. The training was performed at the Center for Advanced Medical Simulation and Training (CAMST).[122]

Study II involved 54 medical students, 26 male and 28 female, 23 to 47 years old, in their fourth or sixth year of medical studies, attending elective courses in emergency medicine, n=30, traumatology, n=18 or anaesthesia and intensive care, n=6. All participants volunteered and gave informed consent. The courses included didactic lectures in A-B-C-D-E examination and team coordination training following the A-TEAM program. The participants took part in three scenarios as active participants or observers. Whether participants had earlier experience of team training using a patient simulator was not taken into account. The training was performed at CAMST.

In Study III 168 staff members participated in 34 team training sessions in a paediatric emergency ward. 163 individuals, aged between 18 and 67, volunteered to participate in the study with questionnaires; physicians, 26 males and 34 females, nurses, 16 male and 66 female, nurse assistants, two male and 19 female. For each training session, the composition of the team on training was always new, but due to logistics some team members could have participated in this training project or some other kind of simulation training before. Only participants' first scenario experiences were used in the analysis of the questionnaires. Earlier training was taken into account in regression analyses. Five trainers, four men and one woman, all physicians experienced in scenario sessions and paediatric emergency, participated with 34 questionnaires; one trainer 26 times, one trainer four times, one trainer two times and two trainers two times. The training was conducted at the Emergency Department at Karolinska University Hospital Huddinge.

Photo 3: Teamwork training in an authentic emergency room.
(*Photo: Lisbet Meurling*)

In Study IV: 152 staff members participated in *in-situ* team training at an ICU. All but one, 151 volunteered to participate in the study, aged between 20 and 62 years; physicians, 21 males and 30 female, nurses, eleven males, 64 females and nurse assistants, all females. Before the *in-situ* team training, the staff took part in a 4-hour interactive seminar on human factor issues which was repeated 16 times. The training was repeated 28 times. The training was conducted at the Intensive Care Unit at the Department of Anaesthesia and Intensive Care at Karolinska University Hospital Huddinge.

3.4 LOGISTICS FOR SAMPLING AND NUMBER OF VIDEOS AND QUESTIONNAIRES

Study I: Separate pre-training and post-training trials were video-recorded for a total of 30 videos. The videos were analysed over 4 months after sampling by 3 observers (a consultant anaesthesiologist, junior psychologist and senior research psychologist) using EMCRM. The participants' attitudes towards safe teamwork before and after training were monitored using the short version of the Operating Team Resource Management Survey (OTRMS) (n=15 pre- and post-training).

Study II: All three scenarios in each of the 12 training session were video-recorded. Videos from 36 scenarios were thus analyzed. Individual teamwork behaviours were assessed using the A-TEAM program. Clinical performance, time to call for help and the frequency of top-toe examinations and of team sum-ups were also measured from the videos. Self-efficacy (n=51) was assessed pre- and post-training.

Concentration (n=46) and mental strain (n=46) were assessed immediately after each scenario. For the flow sheet see Figure 2, and for the targets for training see Table 2.

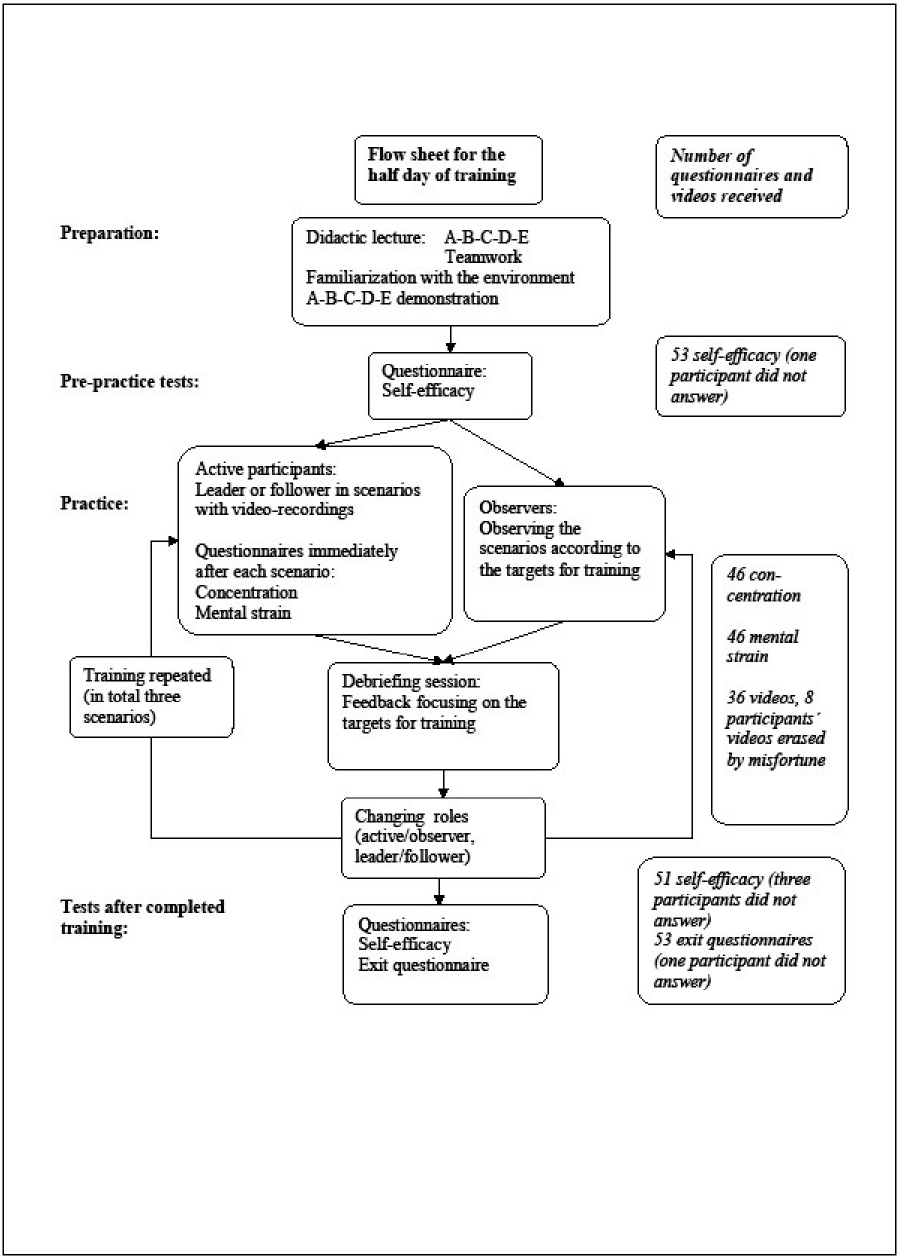


Figure 2: Flow sheet and collected data

Meurling et al BMJ Qual Saf 2013, permission II.

Targets for training	Method	Analysis	Note
Behaviour (1-5):			
1. Take a team member role 2. Gather information and communicate 3. Contribute to a shared understanding of the situation 4. Make collaborative decisions 5. Coordinate and execute tasks	The A-TEAM program, not yet validated was used. Separate videos were used for calibration of rating. Active participants' behaviours were analysed blind by two raters. They observed the study videos individually at random in three minute sequences.	Each active participant was individually graded on a four-level scale (poor, in need of improvement, good, proficient). Team members were categorized as either leader or follower by applying the behavioural elements for "Leader" and "Follower" respectively from the category "Takes a team member role" in the A-TEAM program. For example a leader takes the initiative to provide structure and direct teamwork and task work while a follower challenges constructively and assumes assigned responsibilities.	Annotation 1
Clinical performance (6-7):			
6. Time to call for help in seconds (s)	A standardized measure of call for help was calculated as a ratio by dividing 60 seconds with the team's measured time in seconds.	The time from the entrance of the first active participant into the scenario until the team called for help was measured.	Annotations 1 and 2
7a. Frequency of top-to-toe examinations ($n * h^{-1}$)	The average frequency was calculated as the number of examinations divided by the length of the scenario. A standardized measure was calculated as the ratio between the team's measured frequency and the specialist team's reference frequency.	The number of top-to-toe physical examinations the team completed in a scenario was counted.	Annotations 1 and 2
7b. Frequency of team sum-ups ($n * h^{-1}$)	The average frequency was calculated as the number of sum-ups divided by the length of the scenario. A standardized measure was calculated as the ratio between the team's measured frequency and the specialist team's reference frequency.	A sum-up includes the patient's present problem, clinical background, vital functions, and further plan. The number of team sum-ups performed during a scenario was calculated.	Annotations 1 and 2
Medical management (8):			
8. Stabilize the vital functions of the patient	Time in seconds.	The time from the entrance of the first active participant in a scenario until stabilization of the vital functions of the patient was measured.	Not used (see Results)

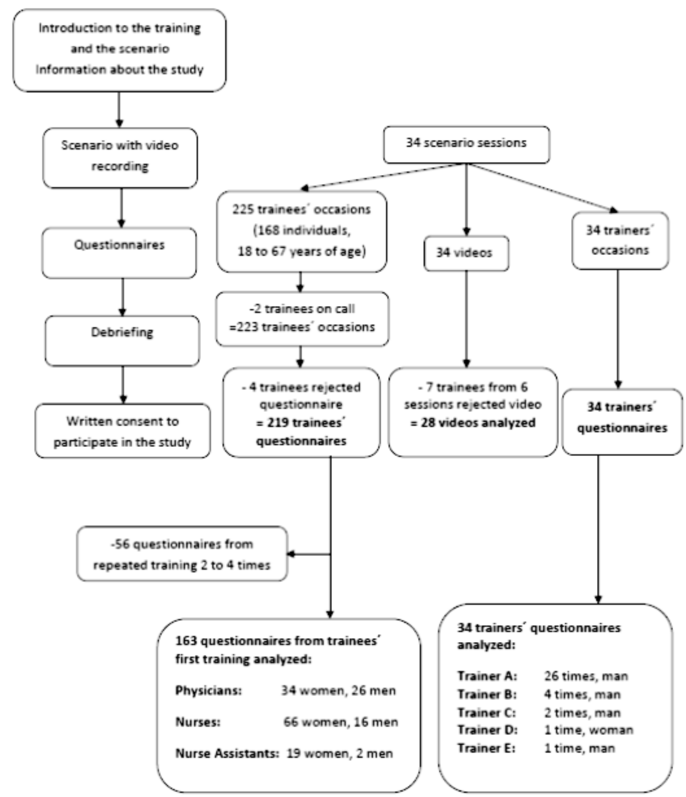
Table 2: Targets for training and video analyses.

Meurling et al BMJ Qual Saf 2013, permission II.

Study III: All scenarios were video-recorded with consent from the participants. After training, they had the opportunity to give written consent. Seven participants from six training sessions rejected video, thus 28 of the 34 videos could be analysed. The first 16 sessions were performed using the LFM, a plastic doll. The following two sessions were performed with a HFS and LFM. Eventually 16 sessions were performed using a HFS.

From the video, the teams' clinical performance was measured as a team effort. Immediately after each scenario, mental strain and flow experience were assessed by both the trainees and the trainers. During each scenario, a research assistant not involved in the scenario counted in real time the number of interventions or interruptions with additional clinical information made by the trainer.

After training, trainees were also asked to respond an exit questionnaire with the following prompts: "Mention the three best elements or moments in the training" and "Mention three elements or moments in the training that need to be improved". For the flow sheet of the training, videos and received questionnaires see Figure 3.



Thirty-four teams were trained following the same schedule. The figure presents the number of questionnaires and videos received and analyzed.

Figure 3: Flow sheet for the training and videos/questionnaires received.

Study IV: The self-efficacy (n=102 pre- and post-training) and SAQ for safety attitudes (n=114 pre- and post-training) was distributed twice, once before training and once after the project. Staff turnover and sick-leave were analysed in the ICU studied and a reference unit from 2006 to 2010, or one year before and after the project.

3.5 TRAINING METHOD

In study I, II and IV the following framework was used for the development of training programs. A training needs analysis was done, bearing in mind the educational levels and thus knowledge, skills and attitudes of each group of participants. The medical tasks for initial care of the patient with vital function failure as well as team coordination demands to maximise utilisation of available resources were identified. The training objectives were then defined; the lectures and the training, including scenarios were planned subsequently and finally target focused simulation-based team training was applied.[10, 15]

At first a didactic, standardized, interactive lecture presented issues of human factors and organizational aspects in emergency and trauma care, as well as the targets for training. The trainees were thereafter familiarized with the simulator, equipment, room and local conditions (e.g., how to call for help). Scenarios were pre-programmed on the simulator and designed to give the participants opportunities to practice the targets. During the scenarios the trainees could call for help when needed. After the scenario, active participants, observers and trainers evaluated the scenario separately according to the targets. A debriefing session was then facilitated by an experienced trainer. Active participants started by giving their conclusions about their own performance, then the observers shared their comments and finally the trainer gave a concluding summary with a few take-home messages.

In study III a briefer form of team training method was applied due to time constraints, but it still followed the sequence of information, demonstration, practice and feedback. The students were introduced to the simulator and equipment and given a short pre-briefing about team behaviour and some clinical skills. After the training a short debriefing was conducted. The scenarios were pre-programmed in the HFS but obviously not in the plastic dolls.

3.6 SIMULATORS

Studies I, II and IV used the Human Patient Simulator; Medical Education Technologies Inc., Sarasota, Florida, USA.

Study III used 2 ordinary plastic dolls of 1 baby and 1 small child as LFMs. The HFS simulators used were paediatric patient simulators: PediaSIM ECS and BabySIM ECS, Medical Education Technologies Inc., Medical Education Technologies Inc., Sarasota, Florida, USA.

3.7 CLINICAL PERFORMANCE

In study III, the team's clinical performance was measured as the time elapsed (s) from the start of the scenario until oxygen was prescribed and the time elapsed (s) from the start of the scenario until oxygen was delivered.

3.8 TEAMWORK BEHAVIOURS

Study I: EMCRM is an instrument to rate crisis management behaviours developed by Gaba and colleagues at Stanford University.[63] It includes ten verbally anchored behavioural items rated on a 5-point scale ranging from 1 (not acceptable) to 5 (excellent) and in this case also an eleventh item for a global rating of "overall team leadership skills". Based on the videotapes, this instrument was used to grade behaviours.

Study II: The A-TEAM program, which also grades followers' teamwork behaviours, was used to assess behaviours from the videotapes.[36] This program includes five categories of behaviours, the first of which is divided into three subcategories. All categories assign four grades for described elements of behaviour: poor, in need of improvement, good and proficient.

3.9 INDIVIDUAL EXPERIENCES AND ATTITUDES

3.9.1 Self-efficacy

Study II: Self-efficacy was self-assessed at the start and at the end of training using a four-item questionnaire. Each proposal was rated on a 7-point Likert scale, in which 1 = not true at all and 7 = very true. The score was calculated as the mean value of all items. Unintentionally only four items from the 5-item scale were used.

Study IV: Self-efficacy was assessed first in the introductory seminar and second when all participants had completed the team training. A five-item questionnaire with the same Likert scale and calculation as in study II was used.

3.9.2 Mental strain

Study II and III: The Borg-CR 10 scale was used to assess the intensity of subjects' short-term mental strain during team training. A feature of this scale is the congruence between verbal anchors and numbers. The verbal anchors were: 0 = nothing at all; 0.5 = very, very little; 1 = very little; 2 = little; 3 = moderate; 5 = much; 7 = very much; 10 = very, very much; • = maximum possible (no verbal anchors were assigned to 4, 6, 8 or 9).[81]

3.9.3 Flow

Study II: Concentration, an important subcomponent of the flow experience, was calculated as the mean of 8 items from a validated flow instrument for assessing aspects of concentration (focusing, time distortion, loss of self-consciousness, telepresence). Participants self-assessed it immediately after each scenario by marking the extent to which they agreed on a 9-point Likert scale, in which 1 = not at all and 9 = very much.

Study III: A flow score (short version) was calculated, according to Jacksons' suggestions, by the mean of nine flow items from a validated flow instrument.[123] Participants indicated the extent to they agreed by marking a 10–point, visual analogue scale (VAS) ranging from "not at all" to "very much".

3.9.4 Attitudes

Study I: OTRMS is a 57-item questionnaire to assess attitudes towards safe teamwork.[91] The short version used in this study has 18 items. Each student answered all items using a 5-point scale ranging from "disagree strongly" to "agree strongly".

Study IV: SAQ is a 64-item, validated instrument to evaluate perceptions of safety climate. From the versions available, this study used the intensive care version, which has been used most commonly on the clinical level, not the individual. The questionnaire has groups of four to seven items assessing six factors: teamwork climate, safety climate, job satisfaction, stress recognition, perceptions of management and perceptions of working conditions. The questions are mixed to not reveal which factor is being measured. Each item is answered using a five-point Likert scale from "strongly disagree" to "strongly agree". In addition to these factors, SAQ has questions about collaboration and communication the respondent has experienced with their own and other professions. These questions are also answered with a 5-point Likert scale from "very low" to "very high". The translation to Swedish was performed by an external, professional translator; a few words were altered to fit the local idiom of the ICU. The questionnaire was then retranslated and sent for review to Professor E. Thomas, University of Texas Houston, who approved the retranslation. According to the original instructions, SAQ data are calculated and presented as mean percentage (SD), although they are ordinal.[124] The scale was converted to at 0–100% scale after the scores for negatively worded items were converted. The data was thus presented as follows: disagree strongly, 0%; disagree slightly, 25%; neutral, 50%; slightly agree, 75%; and strongly agree, 100%.

3.10 STAFF WELL-BEING

Study IV: Staff turnover and sick leave were studied from 2006 to 2010 to encompass the entire study period. Staff turnover was computed as the number of employees quitting their job during one year divided by the average number of employees during that same year. Sick leave was calculated as per cent sick leave taken from scheduled working time. The Department of Human Resources provided anonymous annual data for the ICU studied and a reference ICU at Karolinska University Hospital, Solna. Data could be obtained only for nurses and nurse assistants, not physicians.

3.11 STATISTICS

Study I: To compare pre- and post-training data, a Wilcoxon signed-rank test of difference was used. A probability of <0.05 was considered statistically significant.

Study II: A linear mixed model in procedure Mixed in SAS® (System 9.1, SAS Institute Inc., Cary, NC, USA) was used to analyse the continuous variables, clinical performance and individual experiences.[125] A mixed model with one within-groups factor consecutive scenario (I, II and III) was performed for the clinical performance data. Two fixed factors and the interaction between the factors were included in the mixed model for self-efficacy, the between-groups factor was "sex" and the within-groups factor was "start/end". For concentration and mental strain, a mixed model with two within-groups factors, consecutive scenario (I, II and III) and role (follower and leader), and one between-groups factor, sex was performed.

A generalized estimating equations (GEE) model with the GENMOD procedure in SAS® was performed to analyse the effect on the two raters' scoring of the behavioural categories (Targets 1–5) of the ordinal variables, clinical experience (level of medical studies), order of training scenario (I–III), categorical variables and team members' role (leader, follower) and sex (female, male).[126] A repeated measures design was applied to these data, as all the students participated in more than one scenario with different memberships. A probability (p value) < 0.05 was considered statistically significant.

Study III: In comparison between the two fidelities LFM and HFS regarding clinical performance independent t-test was used and a two-way factorial analysis of variance (ANOVA) was performed when controlling for cases (asthma and sepsis), the statistical unit were teams.

A two-way factorial ANOVA with the factors fidelities and roles was used analysing the individual trainee's assessment of mental strain and experience of flow. A forward stepwise regression analysis was performed to evaluate to what extent variation in mental strain and flow experience could be explained by age, sex, profession, role and previous training with a simulator. P<0.05 was considered statistically significant.

A mixed linear model considering fidelities as the within-subject variable was used to compare the fidelities for the five trainers in mental strain, experience of flow and number of interventions per minutes.

The software used were Statistica 10.0, StatSoft® , Inc. Tulsa OK, USA and SAS® System 9.1, SAS Institute Inc., Cary, NC, USA.

Study IV: Cronbach's alpha was used to calculate internal consistency for self-efficacy and the six SAQ factors. Pearson correlation coefficients were used to measure the association between the six factors of SAQ, and a two-way repeated measure ANOVA was performed to analyse the improvement effect and the difference among physicians, nurses and nurse assistants. Post-hoc contrasts were performed to estimate the improvement effect for each profession. Significant interactions in the ANOVA prompted an examination of simple effects, or the effects of one factor while holding the other factor fixed. Analyses of sex differences in the variables of self-efficacy and SAQ factors using a three-way repeated measure ANOVA were performed due to the uneven distribution of sexes among the professions studied. Multiple regression analyses were performed to analyse the data for staff turnover and sick leave given the independent variables of time, professions, units and interactions with time. P < 0.05 was considered statistically significant.

4 RESULTS

Study I: The behavioural components of leader performance were rated significantly higher with one exception: “utilization of information” after the course, Table 3. The mean inter-rater reliability for the three raters was 0.68.

Table 3. Results of the EMCRM before and after training.

	n = 15, mean (range)		
Teamwork competencies	Before	After	P-value
1. Knowledge of the environment	1.9 (1–3)	2.6 (2–3)	0.004
2. Anticipation of and planning for potential problems	1.8 (1–3)	2.5 (2–3)	0.005
3. Assumption of leadership roles	1.7 (1–3)	2.7 (2–3)	0.001
4. Communication with other team members	2.0 (1–3)	2.7 (2–3)	0.001
5. Distribution of workload ⁄ delegation of responsibility	1.5 (1–2)	2.7 (2–3)	0.001
6. Attention allocation	1.9 (1–3)	2.5 (2–3)	0.033
7. Utilisation of information	2.0 (1–3)	2.3 (2–3)	0.102
8. Utilisation of resources	1.9 (1–3)	2.2 (2–3)	0.025
9. Recognition of limitations ⁄ call for help early enough	1.9 (1–3)	2.3 (1–3)	0.034
10. Professional behaviour ⁄ Interpersonal skills	1.9 (1–3)	2.5 (2–3)	0.007
11. Overall team leadership skills	1.9 (1–3)	2.6 (2–3)	0.004

Wallin et al Medical Education 2007, permission I.

In contrast to the behavioural ratings, only one item on the OTRMS questionnaire showed significant change before and after training. The participants agreed more strongly with the negative statement that “there are no circumstances where a junior team member should assume control of patient management”. Mean (IQR); before 4.4 (3.0-5.0), after 4.7 (4.0-5.0), p=0.025.

Study II: The clinical performance did change significantly in response to training for only one variable measured: an improvement in the frequency of sum-ups (p=0.04). The time to call for help and the frequency of top-to-toe examinations did not change. Individual teamwork behaviours did not show any change between consecutive scenarios I, II and III (p 0.07 to 0.97). Team behaviours were not influenced by sex (p 0.33 to 0.98) or type of course (p 0.24 to 0.90). Both raters (p=0.00 and p=0.02 respectively) agreed that participants were rated higher on the item “gather information and communicate” in the role of leader than in the role of follower.

No sex difference was found for individual experiences. Cronbach’s α before training was 0.87 for self-efficacy. Self-efficacy increased for all from a mean (SD) of 5.15 (0.12) at the start of the training session to 5.42 (0.12) at the end, with a mean difference of -0.267 (p=0.043 (95% Cl -0.526 to -.008). Analysing concentration in scenario I, Cronbach’s α was 0.78. Concentration and mental strain did not change over the main effect, consecutive scenario (I–III) and the interaction between consecutive scenarios (I–III). Role (leader, follower) was not significant either. Participants experienced higher levels of both concentration and mental strain in the role of leader than in the role of follower, and the differences could be generalized to all three scenarios.

Study III: Analysing the variables for clinical performance, the time to prescribe oxygen was numerically longer with a HFS, however statistical significance was not reached, $p=0.058$. Time to deliver oxygen was significantly longer using a HFS, $p=0.014$. Case did not influence these results to a large extent.

Trainees' mental strain and experience of flow did not differ between the two fidelities. However a subgroup analysis showed that leaders reported higher mental strain than followers when using the HFS. Even when mental strain and flow using LFM and HFS were analysed together, leaders reported higher mental strain than followers, but flow experience did not differ between the two roles.

Trainers reported higher mental strain and experience of flow when using HFS. Their number of interventions per minute was significant lower with HFS, $p<0.001$.

The trainees' evaluation of the training in the exit questionnaire exhibited a more positive attitude towards training using a HFS.

Study IV: The internal consistency for self-efficacy was 0.89 before training and 0.90 after the project. Both sexes' scores for self-efficacy were improved, $p<0.0001$, after the project, but there was a greater effect for men. There was no difference between sexes in the level of scores for self-efficacy before training and after the project.

Data is shown in figures 4 and 5 for the percentage of each profession reporting "high" or "very high" quality of collaboration and communication between themselves and the professionals in the ICU. Nurse assistants reported significantly improved quality of collaboration and communication with physicians (specialists) after the project.

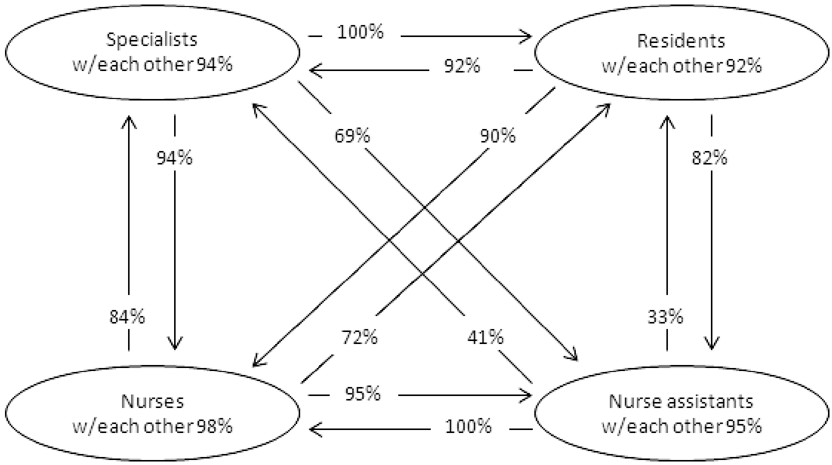


Figure 4: Per cent (%) reporting good collaboration and communication *before* training.

Meurling et al BMJ Qual Saf 2013, permission IV.

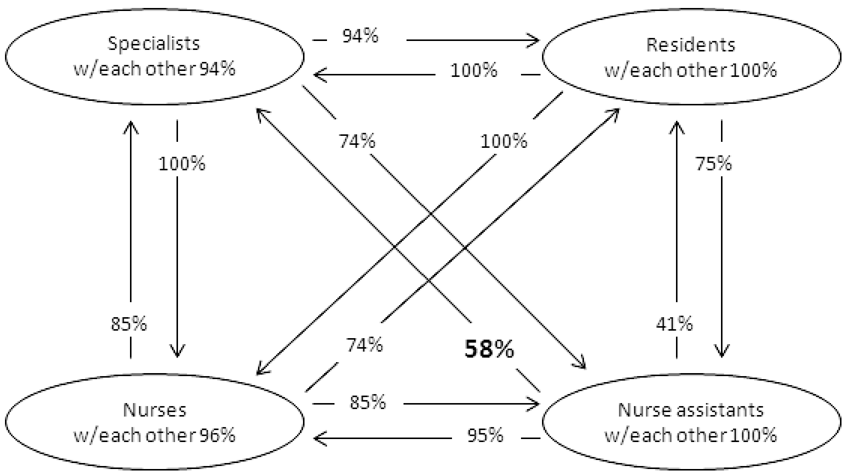


Figure 5. Per cent (%) reporting good collaboration/communication *after* the project.

Meurling et al BMJ Qual Saf 2013, permission IV.

Compared to data before training (Fig. 4) the only difference was among assistant nurses who reported better collaboration and communication with specialists (58% vs. 41%, p=0.04).

The Cronbach's alpha for the SAQ factors varied between 0.43 and 0.71 before and 0.61 and 0.75 after the project. The SAQ factors showed a fair to moderate inter-correlations relationship (0.25 – 0.55) with the exception of the factor of stress recognition, which had a very weak relationship with most of the other factors. There was no difference between sexes concerning level of scores of SAQ factors before SBTT and after the project.

The reported levels of SAQ factors below are presented before training and after the project for all professions: physicians, solid blue line; nurses, red dashes; nurse assistants green dots, Figure 6-8. Vertical bars denote 0.95 confidence intervals.

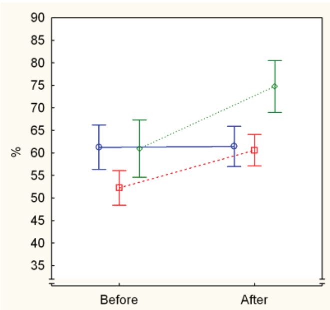


Figure 6: Teamwork climate. The difference between before and after for physicians was 1.09% (95% CI -2.67 to 4.87), for nurses 2.79% (95% CI -0.13 to 5.72) and for nurse assistants 6.61% (95% CI 1.74 to 11.5).

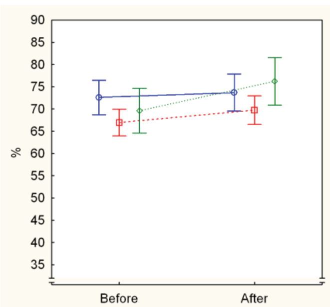


Figure 7: **Safety climate.** The difference in safety climate scores between before and after for physicians was 0.20% (95%CI -4.61 to 5.01), for nurses 8.37% (95% CI 4.63 to 12.1) and for nurse assistants 13.8% (95% CI 7.59 to 20.0).

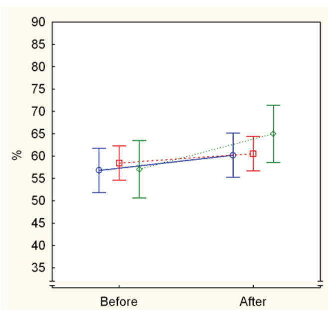


Figure 8: Working conditions. The difference in working conditions scores between before and after for physicians was 3.39% (95%CI -1.21 to 8.00), for nurses 2.08% (95% CI -1.49 to 5.66) and for nurse assistants 7.94% (95% CI 1.99 to 13.9).

The annual changes in the number of nurses quitting their job in the two wards was significantly different, p = 0.006, with a larger reduction in the intervention ICU. There was a significant difference (p = 0.003) in the change in annual sick leave by nurse assistants in the two ICUs, with a larger reduction in the intervention ICU.

Summary of results for study IV:

- Physicians experienced improved self-efficacy after the project but not in their quality of collaboration and communication with physicians (specialists and residents), nurses and nurse assistants. They scored higher than nurses in safety climate before the project period. Their scores for the SAQ factors were not increased after the project period.

- Nurses' self-efficacy improved after the project, but their experienced quality of collaboration and communication with own and other professions did not change. Nurses scored significantly lower than both physicians and nurse assistants in safety climate before SBTT. Their scores for safety climate were higher after the project and ended on a par with physicians' perceptions.

- Nurse assistants' perceived self-efficacy was not improved significantly after the project. They experienced quality of collaboration and communication with physicians (specialists) more favourable. They showed nearly the same level as physicians before the project in scoring of teamwork climate, safety climate and working conditions. Unlike the other professions, nurse assistants' scores for teamwork climate, safety climate and working conditions were higher after the project, matched by a reduction in sick leave.

5 GENERAL DISCUSSION

5.1 PARTICIPANTS

Teamwork training using simulation involves different educational levels of participants, sexes, all roles and professions within the team as well as the trainers.

In study I the participants were third-year medical students with no earlier experience of trauma care or team training and in study II fourth- or sixth-year medical students. In studies III and IV the participants were full medical professionals; study III involved staff in a paediatric emergency ward and study IV, ICU staff. These different educational purposes require an adaptation of the curriculum. The targets and scenarios were adjusted to meet the participants' educational levels. Participants were sometimes eager to learn; even attending voluntary courses. Others were obliged to participate, due to the fact that professional staff was scheduled for training. These differences are challenging and exciting for the trainers, who need to be well educated to fulfil their assignment. It was desirable to apply a new training program to participants with different educational levels to be able to begin the evaluation and refinement of the program.

The sex of the participants did not influence the results to a larger degree in contrast to the role as leader-follower and type of profession. Cross-training, as a leader or follower, was applied to the medical students in study I, II and to some extent to the professionals in study IV. It is used to increase understanding of each other's roles in order to improve the teams' anticipatory behaviour.[14] In study II the students were their own controls regarding differences in individual behaviour and experiences between the role of leader and of follower. As novices, medical students provide an excellent group to study. Professions, nurses and physicians, have been studied before and differences in their experience of collaboration and communication and culture have differed.[92 93, 94 95, 96, 102],[103] This thesis is unique in describing data also for nurse assistants as well as for trainers.

5.2 TRAINING METHOD AND EVALUATION

The training method with a highly structured curriculum and a restricted number of targets described in study I was also used in studies II and IV with stepwise higher levels of education among participants. Kirkpatrick four levels of assessment; reaction, learning, behaviour/transfer and results, have been discussed in detail for many years and recently on how to apply to higher education.[59, 60] As in all team training studies, the optimal goal would have been to study transfer of behaviour to the clinical situation and the impact on patient safety. When training medical students or single individuals from a ward, one must realise that the post-training environment may not provide circumstances, such as the culture for example, to immediately practice all learned behaviours or skills, while nearly all staff at a ward or department, as in studies III and IV, have participated in team training. In addition, in emergency health care where new compositions of teams are created daily due to different cases and staff working schedules, it is extremely difficult to pinpoint the precise effect of individuals' training. However, in the lack of a perfect evaluation method this thesis adopted a multimodal, multilevel (according to Kirkpatrick) evaluation method to collect pieces of data to increase understanding of team training using simulation.

This multimodal approach is in line with the theory proposed by Kraiger et al., amongst others, that training should be evaluated according to its cognitive, skill-based and affective learning outcomes to build a comprehensive picture of the training process.[58, 127]

In study I the results of improved teamwork skills from five training scenarios was promising and encouraged further studies and use of the training method. In addition to individual teamwork behaviours (EMCRM) and attitudes to safe teamwork (OTRMS), participants reactions (open questionnaire) were assessed. The level of evaluation, according to Kirkpatrick, corresponded to one and two.

In study II this same training method was used to study the early phase of training, including assessing individual teamwork behaviours (A-TEAM), individual experiences, self-efficacy, mental strain and concentration, an important subcomponent of flow. In this early phase, self-efficacy improved and the roles of leader and follower showed differences in individual behaviours and experiences, but no changes in teamwork behaviour and only minor changes in clinical performance were noticed. The increased self-efficacy and improvement in clinical performance strengthen a positive learning outcome even during the early phase of training. The level of evaluation according to Kirkpatrick was two.

In study III the training curricula and logistics for training were already set since long time and customised to time constraints at the emergency ward. This study focused on the importance of equipment fidelity. There was only time for one scenario and a few minutes for questionnaires, limiting the number of measurements. The clinical performance of the teams and the frequency of interventions by trainers were assessed during training. After training, trainees' and trainers' mental strain and flow experience was registered as well as the trainees evaluation of the training. Thus the level of evaluation according to Kirkpatrick was one, i.e. reactions.

In study IV the participants estimated self-efficacy, their perceived collaboration and communication and the safety culture at the ward moved in a positive direction between before training and after the project, with a diverse response for professions. In addition nurses and nurse assistants' turn-over and sick-leave were registered and compared with another intensive care unit. A parallel study evaluating the project at the intensive care unit described changes that suggested at least some transfer of what had been trained and discussed, thus Kirkpatrick level three was reached.[128] In this study the goal was to reach Kirkpatrick level four, but assessing changes in patient outcomes was not possible in a single ward study with very uneven distribution of the type of intensive care cases, especially since the system for registration of complications and outcomes was changed during the project period. Therefore staff turnover and sick-leave were chosen as measures.

5.3 CLINICAL PERFORMANCE

Clinical performance is a team task based on medical knowledge and teamwork behaviour. It can be assessed in many ways and all measurements used have to be adapted to the participants' educational level and the scenario used. In study II there was significant improvement only in the frequency of sum-ups in response to half-day SBTT. This limited response is in line with the findings of other studies.[129, 130] There is in fact not time to let all participants repeat the scenarios to a desirable extent during half a day. But even training for a short time can be valuable since it hopefully initiates a process of reflection about new skills, behaviour or attitudes that might yield long term benefit. It is advantageous with repeated training to embed the desired targets when such a process has started.

In study III differences between the two levels of fidelity, regarding trainees´ performance were found. Using HFS, the trainees' time to deliver oxygen was longer than using LFM, interpreted as more realistic timing. The trainees had to read and interpret figures on monitors like in an authentic clinical situation in contrast to the training with LFM. The trainer had to deliver physiologic values to the team verbally during training using a LFM, thus as no surprise; the trainers' frequency of interventions was lower than when using a LFM. During team training, the trainer is occupied with running the scenario and at the same time observes the trainees and prepares for feedback with quality. These task might tax the limited capacity of the human working memory.[65] By using functional magnetic resonance imaging (fMRI) and psychological experiments in humans, de Fockert and collaborators demonstrated that when a person's working memory is occupied, the brain cannot filter out distracting sights in a separate attention task. Thus they suggested that working memory serves to control visual selective attention in the normal human brain.[131] Using a HFS minimises the practical work during the scenario and mental capacity can be released for observation of individuals during training and preparation of feedback.

Photo 4: Teamwork training at CAMST.
(Photo: Lisbet Meurling)

5.4 TEAMWORK BEHAVIOUR

Proficient teamwork behaviour is the ultimate receipt that the culture and individual values permit, or perhaps even value highly, the importance of human factors for patient safety.

In study I teamwork skills improved after training in five scenarios with separate pre- and post training assessment. The students were novices, thus permitting a steep rise in proficiency gain. EMCRM was a feasible assessment instrument for this setting in which leadership performance was rated. However, the training method emphasises the importance of both leaders and followers and the importance of membership was highlighted by cross-over training.[14] Participants changed roles as leaders or followers between scenarios, which can increase understanding of the difficulties specific to each role and thus enhance learning.[37] Rapid shifts of roles, depending on the situation, were encouraged. This approach is in line with other findings; for example, shared leadership increased the effectiveness of anaesthesia teams in situations with high task complexity, and along with others, the authors of this study thus advocated training in shared leadership.[46, 132] Bergman et al concluded that teams with shared leadership experienced less conflict, greater consensus and higher intra group trust.[133]

As a consequence of the conviction of the view on team members' roles in combination with the work with study I, the desire for a scale for team and membership performance acknowledging both roles was obvious. The CRM-based A-TEAM program, developed and described earlier, was used in study II and IV.[36]

In study II the participants took part in three scenarios but no pre- or post-training scenarios for assessment. Teamwork behaviours showed no change after training. The new A-TEAM program was used in this study. While using a new program and scale to assess teamwork behaviour and skills arguably has limitations, the failure to improve teamwork behaviour was in line with earlier studies reporting limited changes in the early phase of SBTT.[129, 130] Using the A-TEAM program made it possible to separate the teamwork behaviour of the different roles during assessment. Leaders communicated more than followers, a reasonable finding since leaders directs team and task work, confirms and verbalizes decisions.

There was no difference in behaviours between the leader and follower roles regarding the other four categories of teamwork behaviours; "takes a team member role", "contributes to a shared understanding of the situation", "contributes to collaborative decisions", and "coordinates and execute tasks", a finding in line with recent studies on shared leadership.[45] In conclusion, even distribution of leadership behaviours among team members is associated with better performance and results according to research, which further strengthens the use of this strategy for teamwork training.[46, 132]

5.5 INDIVIDUAL EXPERIENCES

5.5.1 Self-efficacy

In study II self-efficacy in the ability to understand and manage an emergent clinical situation increased among the students in response to a half-day SBTT. Also in study IV, self-efficacy among physicians' and nurses' was stronger after the project with one-day SBTT. In the latter study there was a sex difference, where men showed a larger improvement. During the SBTT the followers were encouraged to take a more active role, thus giving the leaders increased support. The leaders, often physicians or nurses, thus feel more confident as reflected in increased self-efficacy. Improved self-efficacy concerning crisis management, medical management, clinical performance and teamwork in response to simulation-based training has been shown by others.[72, 134-136]

5.5.2 Mental strain and flow

The results of study II indicated a higher degree of challenge during training for leadership skills than follower skills; higher mental strain and concentration (a subcomponent of flow) was experienced in the role of leader.[82] In study III analysing individual experiences using a HFS, leaders scored a higher mental strain than followers did, confirming the findings of study II. These findings are coherent with Finan et al's study where there were no differences between neonatal low- and high-fidelity simulators concerning trainees' performance, non-technical skills, subjective short-term stress or salivary cortisol, but the leader role correlated with increased salivary cortisol levels.[68] The results partially explain the desire among trainees to be the leader. It is simultaneously challenging and rewarding.

The trainers in study III scored lower mental strain and higher experience of flow using a HFS. These findings support the hypotheses above that the trainers are unloaded using a HFS and can focus more on the task, attaining better balance between challenges and competence.[137] How the instructors feel about their ability to facilitate has a perceived effect on students learning according to Harder et al.[138] Thus, studying trainers and their experiences could be valuable for the development of the training process.

5.5.3 Experienced quality of collaboration and communication

The percentage of each profession reporting high or very high level of collaboration and communication before and after the training period followed the pattern reported in earlier studies, physicians being more positive than nurses.[92, 93, 96] This might be an expression of hierarchies, patient-care responsibilities, training or communication traditions.[93, 139] According to data from Helmreich et al, medicine seems to have strong and distinctive professional cultures, where values and norms are passed on to recruits.[91]

The nurse assistants' experience of quality of collaboration and communication with physicians was significantly higher after the project in study IV. The experiences of nurse assistants have not been previously described in the literature. The findings of study IV are supported by the results in a qualitative study using observations and interviews describing this project. The participants reported increased awareness of the importance of effective communication for patient safety.[128] Improved communication is an important finding. Impaired communication is a well-known cause of adverse incidents and effective collaboration and communication is essential for improving quality and safety in acute care, e.g. ICU..[13, 56, 105, 140]

Estimating the experienced quality of collaboration and communication appears to be an easy, promising, straightforward measurement for future studies.

5.5.4 Safety culture

5.5.4.1 OTRMS

The attitudes towards safety measured by OTRMS did not change after training of medical students in five scenarios. The OTRMS was under development when used and later revised. Unlike study IV in which attitudes improved after training, this first study devoted minimal time to providing knowledge about teamwork and safety. The students were not part of a professional working culture during training, as in study IV, and had only a few days for reflection. Altogether these conditions were not sufficient to produce detectable changes in student's attitudes towards safety.

5.5.4.2 SAQ factors

Cronbach's alpha and inter-correlations for the SAQ factors showed lower values than the benchmarking data; therefore, the results must be interpreted with caution.
The perception of the safety climate in the ICU studied was somewhat lower than in earlier research on ICUs in the United Kingdom, New Zealand and the United States and even lower than the perception of safety culture in Swedish pharmacies with the exception of the factor of stress recognition.[100, 117] Thus the level of safety culture seems to be associated more with the workplace, in this case an ICU, than the country.
Discrepant attitudes about teamwork between physicians and nurses are shown in a number of studies some from ICUs as well as other units.[92-95, 141, 142] This study also includes nurse assistants attitudes, to our knowledge not previously described. Nurse assistants' perceptions of teamwork climate, safety climate and working conditions in the ICU were more positive after the project compared to nurses and physicians. Nurses' scores for safety climate were also improved after the project. Improved perception of teamwork after team training or other team-process-oriented interventions in health care, is in agreement with other research.[17, 50, 103, 110, 143] Physicians did not change in scores for the SAQ factors in this study, earlier studies show scattered results. Khoshbin et al found improved safety climate scores for nurses but not for physicians after implementation of a briefing intervention but Carney et al found a positive change in teamwork climate for both physicians and nurses after implementation of a medical team training program.[103, 144] Interestingly, the nurse assistants thus accounted for the largest number of changes among all professions in the study.

All findings in this ICU study cannot be attributed to the effect of the SBTT project alone because several projects to improve inter-professional collaboration were conducted simultaneously at the unit. However, the systematic SBTT was the only major project to involve all professions, including nurse assistants. Expectations about inter-professional relationships differ according to level in the hierarchy. Those higher in the hierarchy tend to be more satisfied with relationships than subordinates, according to an analysis of inter-professional relationships in healthcare, using power analysis and social role theory or the principle of least interest.[141, 145]. SBTT using the A-TEAM programme recognises all team members, reduces hierarchy and re-models relationships within the team and thus better acknowledges nurses and nurse assistants than traditional methods. This might explain the positive changes in mean values for nurses' and nurse assistants' scores for teamwork climate after the project. These changes were further strengthened by interviews in a qualitative study by Sandahl et al., in which both the nurse manager and some nurses suggested that the SBTT had dealt with the work-roles of the nurses and nurse assistants.[128] As mentioned earlier, the results for the SAQ factors must be interpreted with caution; surveys used in a different context, e.g. geographical than developed for, must be validated appropriately even though a professional translation is done, thus further refinement of the Swedish version of SAQ is needed.[146] The experienced quality of collaboration and communication is probably a more reliable measure in this study. However, this measurement was in line with and thus strengthens the findings that the teamwork climate, experienced collaboration and communication between nurse assistants and physicians improved after the project. These different pieces point towards the same finding: Physicians, nurses and especially nurse assistants benefited from the SBTT.

5.6 STAFF WELL-BEING

Among the intensive care nurses studied in paper IV, there was an indicative reduction for quitting their job in line with an earlier study which found improvements in teamwork climate, safety climate and nurse turnover rates after implementing a safety program.[110] Nurse assistants in the same ICU decreased their sick leave comparing before and after the project. However, this finding should be interpreted cautiously because major changes in the nurse assistants' working conditions were made the year before the project started; thus, there are other plausible explanations and bias cannot be excluded. Sick leave by hospital physicians was associated with poor teamwork in a Finnish study, but the literature offered no support for such an association among nurse assistants.[118]

5.7 FUTURE RESEARCH

Given these studies, validation of the A-TEAM scale and refinement and validation of the Swedish translation of the ICU-version of the SAQ are planned. It would be of interest to further investigate participants' individual experiences of teamwork training, especially in the two roles of leader and follower. Future studies might also explore whether fully qualified professionals show similar responses in the roles of leader and follower in clinical practice and during training. Trainers' experiences and behaviour during training is also of interest in order to provide the optimal conditions for training. Large scales studies looking at transfer effects of SBTT on patient outcomes are of utmost interest. It would also be interesting to study performance decay. In order to reach Kirkpatrick level 4, large resources must be provided and multiple centers involved.

6 GENERAL CONCLUSIONS

This thesis describes a multimodal and multilevel evaluation of simulation based team training (SBTT) examining leaders and followers of students and professionals within a team as well as the trainers.

- Target-focused, scenario-based teamwork training during a one-day course including five scenarios improved the individual team skills of medical students but had no immediate effect on attitudes towards safe patient care.

- During the early phase of SBTT individual experiences, in this case self-efficacy and to some extent clinical performance, improved but individual teamwork behaviour among medical students did not. Leaders and followers exhibited different responses. Training in the role of leader was associated with higher levels of mental strain and concentration and a higher degree of communication.

- Comparing a low-fidelity model with a high fidelity simulator (HFS) during SBTT in one paediatric scenario with a team of full professionals in situ in an emergency room; the trainees' time to deliver oxygen was significantly longer with a HFS, interpreted as more realistic timing. Leaders experienced higher levels of mental strain during training with a HFS. Trainers had a lower frequency of interventions, reduced mental strain and higher experience of flow using a HFS. These findings indicate a potential for trainers to focus more on trainees' behaviours and performance during training.

- After SBTT of the entire staff in an ICU, participants increased their scores of self-efficacy, experienced quality of collaboration and communication between professions and perceptions of teamwork, safety and working conditions. Positive changes in staff turnover and sick leave were observed. Physicians, nurses and especially nurse assistants benefited from the SBTT. However it was expressed differently among the professions.

These findings have several implications for training and feedback. They emphasize the need to design training curricula and scenarios taking into consideration the different needs of leaders, followers and also different professions. High-performing learning organizations foster the growth of professional staff of the benefit of patient outcomes. Learning is not only a concern of students; life-long learning applies to all health care professionals in order to achieve and maintain excellence in clinical performance.

Material and methods	**Study I**	**Study II**	**Study III**	**Study IV**
Study design	Observational cohort study	Observational exploratory cohort study	Case-control study	Observational cohort study (case control design for sick leave and staff turnover)
Aims	To describe in detail a target-focused instructional strategy applied to a medical team and to evaluate the outcome of this strategy on team behaviours and attitudes.	To explore individual experiences associated with learning and performance, levels of mental strain and concentration for leaders' and followers' separately during the early phase of simulation based team-training (SBTT) and their perceived self-efficacy pre- and post-training. Data was also sampled for the training outcomes: individual behaviours and team endeavour in clinical performance	To study trainees' and trainers' performance, mental strain and flow experience during training using a low fidelity model (control) or a high-fidelity patient simulator (case) in an authentic emergency room. In addition the trainees evaluation comments was registered in an exit questionnaire. Leaders and followers were studied separately for their mental strain and flow experience during training.	The primary aim of this study was to examine the relationship between simulation based team training (SBTT) in situ and professions (physicians, nurses and nurse assistants) self-efficacy, experienced quality of collaboration and communication, perceptions of teamwork climate, safety climate and working conditions. As a secondary aim, the influence of working conditions on changes in staff turnover and sick leave were examined.
Hypothesis	Teamwork skills and attitudes will improve in response to target-focused scenario-based teamwork practice during a one-day course.	Changes in individual experiences can be detected early during SBTT. Leaders and followers will have different responses.	Training with high-fidelity simulators will increase trainees' experience of realism and facilitate the trainers' task, resulting in different behaviour and individual experiences than training with low-fidelity models.	SBTT of the entire ICU staff will improve individual self-efficacy and the perception of quality of collaboration and communication. Additionally, SBTT will improve the teamwork climate, safety climate and perception of working conditions in the ICU. Positive changes in staff turnover and sick leave will be detected.
Participants	Third-year medical students, n=15 (8 women) age 21 to 25	Fourth- or sixth-year medical students, n=54 (28 women) age 23 to 47	Staff involved in paediatric emergencies; n=168 trainees, providing163 questionnaires at 34 occasions, providing 28 videos. Trainees age 18 to 67; 60 physicians (34 women), 82 nurses (66 women) and 21 nurse assistants (19 women) Five trainers, all physicians (one woman)	ICU staff; n=151 age 20 to 62; 51 physicians (30 women), 75 nurses (64 women) and 25 nurse assistants (all women)

Material and methods	Study I	Study II	Study III	Study IV
Simulators	Patient simulator (Human Patient Simulator; Medical Education Technologies Inc., Sarasota, Florida, USA)	Patient simulator (Human Patient Simulator, Medical Education Technologies Inc., Sarasota, Florida, USA)	Two low-fidelity dolls (one baby and one small child) and two high-fidelity patient simulators (PediaSIM ECS and BabySIM ECS, METI Inc., Sarasota, Florida, USA)	Patient simulator (Human Patient Simulator, Medical Education Technologies Inc., Sarasota, Florida, USA)
Video	Yes	Yes	Yes	Yes, but only for debriefing during training, not for assessment
Assessment of team behaviour	Emergency medicine crisis resource management (EMCRM)	A-TEAM program	No	No
Assessment of performance or other measure	No	Trainees: The frequency of team sum-ups, the time to call for help and the frequency of top-to-toe examinations	Trainees: Time to prescribe and deliver oxygen Trainers: Number of interventions per hour	Staff turnover and sick leave
Self-efficacy	No	Yes	No	Yes
Mental strain	No	Yes	Yes	No
Flow experience	No	Yes	Yes	No
Attitudes questionnaire	Operating team resource management survey (OTRMS)	No	No	Safety Attitudes Questionnaire (SAQ)
Exit questionnaire	Yes	No	Yes	No

7 SWEDISH SUMMARY

Patienter och anhöriga har rätt att kräva en sjukvård av hög kvalité. Tyvärr visar studier att frekvensen undvikbara misstag i vården inte är försumbar. Dessa beror ofta på s.k. human factors, d.v.s. den s.k. mänskliga faktorn. Vårdarbetet är komplext och kräver både tekniska och icke-tekniska färdigheter. Det senare omfattar bland annat samarbetsförmåga. Samarbete är en viktig faktor för god och patientsäker sjukvård. I akutsituationer där liv och död står på spel krävs snabba beslut och samarbete mellan människor som kanske aldrig har setts tidigare. Samarbetsbeteende är inte medfött utan går att träna. Simulationsbaserad samarbetsträning (SBTT) är en metod för att träna viktiga icke-tekniska färdigheter (t.ex. samarbete och kommunikation) utan att använda patienter som träningsobjekt. Föreliggande avhandling har utvärderat SBTT ur flera aspekter avseende både läkarstudenter och fullt yrkesverksam sjukvårdspersonal.

Utvärdering kan ske på olika nivåer enligt Kirkpatrick; 1) Reaktion; är deltagarnas omedelbara utvärdering av träningen 2) Lärande; kan provas genom t.ex. ett kunskapsprov eller observation av ändrat beteende i slutet av träningen 3) Beteende d.v.s. överföring av kunskap; färdighet eller attityd från träningen till arbetsplatsen 4) Resultat av träningen i verksamheten; t.ex. förbättrad patientöverlevnad och minskat antal komplikationer. Reaktion och lärande är absolut vanligast att studera i träningssammanhang eftersom överföring till verksamheten och resultat i vården är svåra att säkert koppla till den enskilda personens träning. De två senare utvärderingarna är önskvärda då patientnyttan är det absoluta måttet på lyckad träning. Träningen kan även utvärderas avseende de som tränas och tränarna, avseende olika yrkesgrupper, kön och roller (ledare/följare). Syftet med dessa studier var att genomföra en multimodal utvärdering, på flera nivåer enligt Kirkpatrick, av SBTT på läkarstudenter och på sjukvårdsteam i deras autentiska arbetsmiljö; en intensiv-vårdsavdelning och en pediatrisk akutmottagning.

I arbete 1 deltog 15 läkarstudenter i 5 fullskalescenarier med målbaserad trauma-team träning. Träningen skedde vid Centrum för avancerad medicinsk simulering och träning i Stockholm. Individuella samarbetsfärdigheter förbättrades, men attityden till säkert arbete förändrades inte.

I arbete 2 tränades 54 läkarstudenter i 3 fullskalescenarier (n=36) under en halvdag. Teamets kliniska prestation förbättrades avseende fortlöpande summeringar av det kliniska tillståndet. Deltagarnas självtillit till att handlägga akuta situationer ökade under denna tidiga träningsfas, men deras samarbetsbeteende förändrades inte. I rollen som ledare kommunicerade deltagarna mer än följarna och ledarna skattade sin nivå av mental ansträngning och koncentration högre än vad följarna gjorde.

Arbete 3 utgjordes av en fall-kontrollstudie där en högteknologisk barnsimulator(HFS) jämfördes med en lågteknologisk modell (LFM). 168 personer; läkare, sjuksköterskor och undersköterskor, deltog i träningen indelade i grupper i ett videoinspelat barnscenario. Träningen utfördes i ett akutrum på akutmottagningen, Karolinska Universitetssjukhuset, Huddinge. 17 grupper tränade med LFM och 17 grupper med HFS. Efter samtycke användes 163 deltagarenkäter, 28 videos samt 34 tränareenkäter i studien. Vid användande av HFS var tiden till administrering av syrgas signifikant längre, vilket tolkades som en högre grad av realistisk tidsåtgång i utförande av uppgiften. Deltagarna i rollen som ledare skattade en högre grad av mental ansträngning under träning med HFS. Tränarna halverade antalet interventioner (d.v.s. ingripanden för att beskriva fysiologiska parametrar som inte kan framställas av en LFM) vid användandet av HFS och de upplevde en lägre grad av mental ansträngning samt högre grad av flow. Tränarnas resultat vid användande av HFS tolkades som att det fanns ökad möjlighet att fokusera mer på deltagarnas beteende och prestation under träningen för att kunna leda scenariot och samtidigt förbereda återkoppling.

I arbete 4 tränade all personal (n=152, varav 151 deltog i studien) på intensivvårdsavdelningen Karolinska Universitetssjukhuset, Huddinge, samarbete vid akutsituationer. Träningen genomfördes som en dags in-situ fullskalesimulatorträning under en tvåårsperiod. Efter träningsperioden skattade undersköterskor kvalitén på samarbete och kommunikation med specialistläkare högre och sköterskor och läkare skattade sin självtillit (till att handlägga akuta situationer) högre. Yrkesgrupperna skilde sig åt gällande uppfattning om säkerhetskultur före träning. Efter träningsperioden var undersköterskors skattning av samarbetsklimat, säkerhetsklimat och arbetsförhållanden mer positiva, liksom sjuksköterskors skattning av säkerhetsklimatet. I jämförelse med en kontrollavdelning var antalet sjuksköterskor som avslutade sin anställning lägre och undersköterskornas sjukfrånvaro minskade.

Sammanfattningsvis visar studierna att strukturerad samarbetsträning kan påverka samarbetsbeteendet och skattning av självtillit. Rollen i teamarbetet, d.v.s. ledare eller följare, leder till olika upplevelser, där ledarrollen är mer ansträngande, men där ledaren också upplever högre känsla av flow jämfört med följarna. Graden av hur verklighetstrogen simulatorn är har också viss betydelse, där framför allt tränarna/lärarna troligen har nytta av högteknologiska simulatorer eftersom den mentala ansträngningen minskade. Strukturerad samarbetsträning kan möjligen även förbättra uppfattningen om interprofessionellt samarbete/ kommunikation och säkerhetskultur när all personal på en avdelning tränas. Undersköterskor, sjuksköterskor och läkare påverkas olika av samarbetsträning.

8 ACKNOWLEDGEMENTS

This thesis has been carried out at the Department for Clinical Science, Intervention and Technology (CLINTEC), Karolinska Institutet, Division of Anesthesia and Intensive Care at Karolinska University Hospital Huddinge. I would like to express my sincere gratitude to all those who in either way supported me and made this thesis possible. In particular, I would like to acknowledge:

Professor **Li Felländer-Tsai**, my main supervisor, for your professionalism, for your scientific excellence, for always supporting and guiding me, for sharing your outstanding endless energy and for bringing laughs, encouragement and perspective in tough times, and for bringing resources making this thesis possible.

Carl-Johan Wallin, Md, PhD, my co-supervisor, for introducing me to teamwork training and to the scientific world, for your patience and effort in teaching me structure and how to write, for all support and clarifying discussions, and for understanding that life is more than work.

Professor **Leif Hedman**, my co-supervisor, for sharing and guiding me through your huge knowledge of individual experiences and human memory, for all telephone discussions and quick response on my writing and questions, for all your wonderful jokes giving me energy.

Jan Hedegård, Christer Sandahl, Karl-Johan Lidefelt and **Cecilia Escher**, co-authors, for all your kindness, knowledge, valuable contribution and enthusiastic cooperation.

Professor **Sigridur Kalman**, head of the Division of Anesthesia and Intensive Care at CLINTEC, KI and head of research at the Department of Anaesthesia and Intensive Care,at Karolinska University Hospital Huddinge for your interest and support in my PhD education.

Professor Jan Werneman, for employing me and giving me support and wise advice concerning intensive care and research during the years, for introducing me to Susanna.

Björn Holmström, MD, PhD, head of the Department of Anesthesia, Surgical Services and Intensive Care, for making it possible to combine research and clinical work.

Bengt Eriksson, MD, former head of the Department of Anesthesia, Surgical Services and Intensive Care, for believing in me and the thesis from the beginning

Patrik Rossi, MD, PhD, present head of the Intensive Care Unit, for being an enthusiastic leader and for supporting my research, especially the project at the Intensive Care Unit, resulting in study IV.

Leif Tokics, MD, PhD, former head of the Intensive Care Unit, for supporting the planning and implementation of the project at the Intensive Care Unit.

Inga Tjäder, MD, PhD, former head of the Intensive Care Unit, for supporting the continued execution of the project at the Intensive Care Unit.

Aniitta Nieminen, RN, present head of nurses at the Intensive Care Unit, for supporting the implementation of the project at the Intensive Care Unit and with endless energy working with the staff schedule making it possible.

Elisabeth Berg, BSc, for your skilled statistical assistance and your never ending patience with my questions.

Kajsa Giesecke, MD, PhD, external mentor, for your enthusiasm and sharing your thoughts about work and life.

Susanna Broms, for taking your time sharing your knowledge of life, for supporting and guiding me and introducing me to your favorite café.

Ann-Charlotte Nordström, Sari Peltonen, Marie Eliasson, Karin Malm, Sonja Eriksson, Lena Waldersten and **Åsa G Bengtsson** for your kindness and administrative support.

All colleagues at CAMST, for creating a warm atmosphere to work in, especially **Jane** for being the perfect partner as instructor, **Johan** for being a supportive research mate always sharing your knowledge, **Annika** for attending every single session in study III, **Petter and Mats** for your professionalism running all scenarios in study IV, **Lars-Gunnar and Simon** for your excellent technical knowledge.

All my colleagues at the Department of Anesthesia, Surgical Services and Intensive Care, Karolinska University Hospital, Huddinge, for your support and encouragement, for working in the clinical ward making research possible**. Cathrin,** for your warm sincerity**, Cecilia, Christina, Christina** and **Lena**, all of you for your friendship, thoughtfulness and all we share of joy and sorrow in life.

All staff at the Intensive Care Unit for your enthusiasm and support, making the daily work enjoyable.

All physicians, nurses, nurse assistants and medical students involved in the studies, allowing video-recording and being sustainable with all questionnaires.

All friends, especially **Anna-Lena, Ann, Helene, Marie, Lena, Maria and Johanna** for listening and supporting, for talking and laughing about what matters in life.

My parents **Gun and Gösta** for always loving me, for all your energy, endless help and support.

My sister **Berit** for your love and honesty, even when I don't want to listen, for always being there, very close. **Ann-Marie, Kerstin** and **Eva-Karin** – KDB are the best!

My parents in-law, **Birgitta and Rolf**, for always being nice, for your support and practical help during the years.

Johan, for your love and patience, your never ending support in everyday life and for smart solutions as my 24/7 computer support.

Fredrik and Erika, our children, for your love and laugh, you are the meaning of life.

This thesis was financed by generous research grants from Marianne and Marcus Wallenberg Foundation, Wallenberg Global Learning Network (WGLN), The Stockholm County Council (ALF), VINNOVA, the Department of Anesthesia and Intensive Care at Karolinska University Hospital, the Center for Advanced Medical Simulation and training (CAMST), Department of Clinical Science Intervention and Technology (CLINTEC) at Karolinska Institutet and the Vårdal Foundation.

9 REFERENCES

1 Symons NR, Almoudaris AM, Nagpal K, Vincent CA, Moorthy K. An observational study of the frequency, severity, and etiology of failures in postoperative care after major elective general surgery. *Ann Surg*. 2013;**257**:1-5.

2 Nagpal K, Arora S, Vats A, et al. Failures in communication and information transfer across the surgical care pathway: interview study. *BMJ Qual Saf*. 2012;**21**:843-849.

3 Gaba DM. Human error in anesthetic mishaps. *International anesthesiology clinics*. 1989;**27**:137-147.

4 Baker GR, Norton PG, Flintoft V, et al. The Canadian Adverse Events Study: the incidence of adverse events among hospital patients in Canada. *CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne*. 2004;**170**:1678-1686.

5 Valentin A, Capuzzo M, Guidet B, et al. Patient safety in intensive care: results from the multinational Sentinel Events Evaluation (SEE) study. *Intensive care medicine*. 2006;**32**:1591-1598.

6 Reader TW, Flin R, Cuthbertson BH. Communication skills and error in the intensive care unit. *Current opinion in critical care*. 2007;**13**:732-736.

7 Brennan TA, Leape LL, Laird NM, et al. Incidence of adverse events and negligence in hospitalized patients: results of the Harvard Medical Practice Study I. 1991. *Qual Saf Health Care*. 2004;**13**:145-151; discussion 151-142.

8 Eappen S, Lane BH, Rosenberg B, et al. Relationship between occurrence of surgical complications and hospital finances. *JAMA : the journal of the American Medical Association*. 2013;**309**:1599-1606.

9 Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW. Systems approaches to surgical quality and safety: from concept to measurement. *Ann Surg*. 2004;**239**:475-482.

10 Flin RH, O'Connor P, Crichton MD. *Safety at the sharp end: a guide to non-technical skills*. Burlington, VT Ashgate; 2008.

11 Kohn LT, Corrigan J, Donaldson MS, ebrary I. To err is human: building a safer health system. National Academy Press, Washington, D.C, 2000.

12 Helmreich RL, Davies JM. 3 Human factors in the operating room: interpersonal determinants of safety, efficiency and morale. *Bailliere's Clinical Anaesthesiology*. 1996;**10**:277-295.

13 Manser T. Teamwork and patient safety in dynamic domains of healthcare: a review of the literature. *Acta anaesthesiologica Scandinavica*. 2009;**53**:143-151.

14 Salas E, Cannon-Bowers JA. Methods, tools, and strategies for team training. American Psychological Association, US, 1997; 249-279.

15 Salas E, Cannon-Bowers JA. The science of training: a decade of progress. *Annual review of psychology*. 2001;**52**:471-499.

16 Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *The New England journal of medicine*. 2009;**360**:491-499.

17 Pronovost PJ, Needham D, Hyzy R, et al. Improving patient safety in intensive care units in Michigan. *Journal of Critical Care*. 2008;**23**:207-221.

18 Wayne DB, Didwania A, Feinglass J, Fudala MJ, Barsuk JH, McGaghie WC. Simulation-based education improves quality of care during cardiac arrest team responses at an academic teaching hospital: a case-control study. *Chest*. 2008;**133**:56-61.

19 Buljac-Samardzic M, Dekker-van Doorn CM, van Wijngaarden JDH, van Wijk KP. Interventions to improve team effectiveness: A systematic review. *Health policy*. 2010;**94**:183-195.

20 Salas E, Wilson KA, Burke CS, Priest HA. Using simulation-based training to improve patient safety: what does it take? *Joint Commission journal on quality and patient safety / Joint Commission Resources*. 2005;**31**:363.

21 Delise LA, Gorman CA, Brooks AM, Rentsch JR, Steele-Johnson D. The Effects of Team Training on Team Outcomes: A Meta-Analysis. *Performance Improvement Quarterly*. 2010;**22**:53-80.

22 Knudson MM, Khaw L, Bullard MK, et al. Trauma training in simulation: translating skills from SIM time to real time. *The Journal of trauma*. 2008;**64**:255-263; discussion 263-254.

23 Reznick RK, MacRae H. Teaching surgical skills--changes in the wind. *The New England journal of medicine*. 2006;**355**:2664-2669.

24 Jacobs LM, Burns KJ, Kaban JM, et al. Development and evaluation of the advanced trauma operative management course. *The Journal of trauma*. 2003;**55**:471-479; discussion 479.

25 Weaver SJ, Barker M, King HB, et al. Does teamwork improve performance in the operating room? A multilevel evaluation. *Joint Commission journal on quality and patient safety / Joint Commission Resources*. 2010;**36**:133.

26 Cziraki K, Lucas J, Rogers T, et al. Communication and relationship skills for rapid response teams at hamilton health sciences. *Healthcare quarterly (Toronto, Ont)*. 2008;**11**:66-71.

27 Leonard M, Graham S, Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. *Qual Saf Health Care*. 2004;**13 Suppl 1**:i85-90.

28 Arriaga AF, Bader AM, Wong JM, et al. Simulation-based trial of surgical-crisis checklists. *The New England journal of medicine*. 2013;**368**:246-253.

29 Moorthy K, Munz Y, Forrest D, et al. Surgical crisis management skills training and assessment: a simulation[corrected]-based approach to enhancing operating room performance. *Ann Surg*. 2006;**244**:139-147.

30 Thomas EJ, Taggart B, Crandell S, et al. Teaching teamwork during the Neonatal Resuscitation Program: a randomized trial. *J Perinatol*. 2007;**27**:409-414.

31 Berkenstadt H, Haviv Y, Tuval A, et al. Improving handoff communications in critical care: utilizing simulation-based training toward process improvement in managing patient risk. *Chest*. 2008;**134**:158-162.

32 Surcouf JW, Chauvin SW, Ferry J, Yang T, Barkemeyer B. Enhancing residents' neonatal resuscitation competency through unannounced simulation-based training. *Medical education online*. 2013;**18**:1-7.

33 DeVita MA, Schaefer J, Lutz J, Wang H, Dongilli T. Improving medical emergency team (MET) performance using a novel curriculum and a computerized human patient simulator. *Qual Saf Health Care*. 2005;**14**:326-331.

34 Aggarwal R, Mytton OT, Derbrew M, et al. Training and simulation for patient safety. *Qual Saf Health Care*. 2010;**19 Suppl 2**:i34-43.

35 Larsson J, Holmstrom IK. How excellent anaesthetists perform in the operating theatre: a qualitative study on non-technical skills. *Br J Anaesth*. 2013;**110**:115-121.

36 Wallin C-J, Hedman L, Meurling L, Felländer-Tsai L. Targets for training, feedback and assessment of all OR members' team work. In: Flin R, Mitchel L, eds. *Safer Surgery: Analysing Behaviour in the Operating Theatre*. Ashgate Publishing Ltd, Farnham, 2009; 129-150.

37 McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. *Medical Education*. 2010;**44**:50.

38 Wayne DB, Siddall VJ, Butter J, et al. A longitudinal study of internal medicine residents' retention of advanced cardiac life support skills. *Academic medicine : journal of the Association of American Medical Colleges*. 2006;**81**:S9-S12.

39 Crofts JF, Bartlett C, Ellis D, Hunt LP, Fox R, Draycott TJ. Management of shoulder dystocia: skill retention 6 and 12 months after training. *Obstet Gynecol*. 2007;**110**:1069-1074.

40 Bleakley A, Boyden J, Hobbs A, Walsh L, Allard J. Improving teamwork climate in operating theatres: the shift from multiprofessionalismto interprofessionalism. *J Interprof Care*. 2006;**20**:461-470.

41 Paine LA, Rosenstein BJ, Sexton JB, Kent P, Holzmueller CG, Pronovost PJ. Republished paper: Assessing and improving safety culture throughout an academic medical centre: a prospective cohort study. *Postgraduate Medical Journal*. 2011;**87**:428.

42 Foundation TH. Does improving safety culture affect patient outcome? *The Health Foundation Research Scan*. 2011.

43 Rouse WB, Cannonbowers JA, Salas E. The role of mental models in team performance in complex-systems. IEEE transactions on systems man and cybernetics.. 1992;**22**:1296-1308.

44 Van Vugt M. Evolutionary origins of leadership and followership. *Personality and social psychology review : an official journal of the Society for Personality and Social Psychology, Inc*. 2006;**10**:354-371.

45 Pearce CL, Hoch JE, Jeppesen HJ, Wegge J. New Forms of Management Shared and Distributed Leadership in Organizations. *Journal of Personnel Psychology*. 2010;**9**:151-153.

46 Kunzle B, Zala-Mezo E, Wacker J, Kolbe M, Spahn DR, Grote G. Leadership in anaesthesia teams: the most effective leadership is shared. *Qual Saf Health Care*. 2010;**19**:1-6.

47 Bergman JZ, Rentsch JR, Small EE, Davenport SW, Bergman SM. The shared leadership process in decision-making teams. *The Journal of social psychology*. 2012;**152**:17-42.

48 Biggs JB, Tang C, Ebook L. Teaching For Quality Learning At University. McGraw-Hill Education, Maidenhead, 2011; 95-110.

49 Wilhelmsson N, Dahlgren LO, Hult H, et al. The anatomy of learning anatomy. *Advances in health sciences education : theory and practice*. 2010;**15**:153-165.

50 Weaver SJ, Lyons R, DiazGranados D, et al. The anatomy of health care team training and the state of practice: a critical review. *Academic medicine : journal of the Association of American Medical Colleges*. 2010;**85**:1746-1760.

51 McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003-2009. *Med Educ*. 2010;**44**:50-63.

52 Issenberg SB, McGaghie WC, Petrusa ER, Lee Gordon D, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Medical teacher*. 2005;**27**:10-10.

53 McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. Effect of practice on standardised learning outcomes in simulation-based medical education. *Medical Education*. 2006;**40**:792-797.

54 Holmboe ES, Ward DS, Reznick RK, et al. Faculty development in assessment: the missing link in competency-based medical education. *Academic medicine : journal of the Association of American Medical Colleges*. 2011;**86**:460-467.

55 Murray WB, Foster PA. Crisis resource management among strangers: principles of organizing a multidisciplinary group for crisis resource management. *Journal of clinical anesthesia*. 2000;**12**:633-638.

56 Helmreich RL, Davies JM. 3 Human factors in the operating room: interpersonal determinants of safety, efficiency and morale. *Baillière's Clinical Anaesthesiology*. 1996;**10**:277-295.

57 Yinong YX, Neily J, Mills PD, et al. Association Between Implementation of a Medical Team Training Program and Surgical Morbidity. *Archives of Surgery*. 2011;**146**:1368-1373.

58 Kraiger K, Ford JK, Salas E. Application of Cognitive, Skill-Based, and Affective Theories of Learning Outcomes to New Methods of Training Evaluation. *Journal of Applied Psychology*. 1993;**78**:311-328.

59 Kirkpatrick DL, Kirkpatrick JD. *Evaluating Training Programs : The Four Levels (3rd Edition)*. Williston, VT, USA Berrett-Koehler Publishers; 2005.

60 Praslova L. Adaptation of Kirkpatrick's four level model of training criteria to assessment of learning outcomes and program evaluation in Higher Education. *Educational Assessment, Evaluation and Accountability*. 2010;**22**:215-225.

61 Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *British journal of anaesthesia*. 2003;**90**:580-588.

62 Yule S, Flin R, Paterson-Brown S, Maran N, Rowley D. Development of a rating system for surgeons' non-technical skills. *Medical Education*. 2006;**40**:1098-1104.

63 Gaba DM, Howard SK, Flanagan B, Smith BE, Fish KJ, Botney R. Assessment of clinical performance during simulated crises using both technical and behavioral ratings. *Anesthesiology*. 1998;**89**:8-18.

64 Hull L, Arora S, Kassab E, Kneebone R, Sevdalis N. Observational teamwork assessment for surgery: content validation and tool refinement. *Journal of the American College of Surgeons*. 2011;**212**:234-243.e235.

65 Baddeley A. Working memory: theories, models, and controversies. *Annual review of psychology*. 2012;**63**:1-29.

66 Beaubien JM, Baker DP. The use of simulation for training teamwork skills in health care: how low can you go? *Quality & safety in health care*. 2004;**13 Suppl 1**:i51-i56.

67 Levett-Jones T, Lapkin S, Hoffman K, Arthur C, Roche J. Examining the impact of high and medium fidelity simulation experiences on nursing students' knowledge acquisition. Nurse Education in Practice 2011.

68 Finan E, Bismilla Z, Whyte HE, Leblanc V, McNamara PJ. High-fidelity simulator technology may not be superior to traditional low-fidelity equipment for neonatal resuscitation training. *Journal of perinatology : official journal of the California Perinatal Association*. 2012;**32**:287.

69 Crofts JF, Bartlett C, Ellis D, Hunt LP, Fox R, Draycott TJ. Training for shoulder dystocia: a trial of simulation using low-fidelity and high-fidelity mannequins. *Obstetrics and gynecology*. 2006;**108**:1477-1485.

70 Owen H, Mugford B, Follows V, Plummer JL. Comparison of three simulation-based training methods for management of medical emergencies. *Resuscitation*. 2006;**71**:204-211.

71 MD P, GT B, VM N. *In Situ Simulation: Challenges and Results.* Rockville (MD)Agency for Healthcare Research and Quality (US); 2008.

72 Reznek M, Smith-Coggins R, Howard S, et al. Emergency medicine crisis resource management (EMCRM): pilot study of a simulation-based crisis management course for emergency medicine. *Academic emergency medicine : official journal of the Society for Academic Emergency Medicine*. 2003;**10**:386-389.

73 Bandura A. *Self-Efficacy. The Exercise of Control* W. H. Freeman and Company; 1997.

74 Schunk DH. Goal-setting and self-efficacy during self-regulated learning. *Educational Psychologist*. 1990;**25**:71-86.

75 Nishisaki A, Keren R, Nadkarni V. Does simulation improve patient safety? Self-efficacy, competence, operational performance, and patient safety. *Anesthesiology clinics*. 2007;**25**:225-236.

76 Rosen MA, Salas E, Pavlas D, Jensen R, Fu D, Lampton D. Demonstration-based training: a review of instructional features. *Human factors*. 2010;**52**:596-609.

77 Wickens CD. Multiple Resources and Mental Workload. *Human Factors: The Journal of the Human Factors and Ergonomics Society*. 2008;**50**:449-449.

78 FT E, GF W, AF K, DL G. *Workload assessment in multi-task environments.* . London, GB Taylor & Francis, Ltd.; 1991.

79 NASA TLX. *http://humansystemsarcnasagov/groups/TLX/*, Accessed 21th April 2013.

80 Tattersall AJ, Foord PS. An experimental evaluation of instantaneous self-assessment as a measure of workload. *Ergonomics*. 1996;**39**:740-748.

81 Borg G, Borg E. A new generation of scaling methods: Level-anchored ratio scaling. . *Psychologica* 2001;**28**:15-45.

82 Csikszenmihalyi M, Abuhamdeh S, Nakamura J. Handbook of competence and motivation. In: AJ Elliot AJ, Dweck CS, eds. The Guilford Press, New York, 2005; 598-608.

83 Baker DP, Gustafson S, Beaubien JM, Salas E, Barach P. Medical team training programs in health care. Rockville, MD, 2005.
84 Lingard L, Espin S, Whyte S, et al. Communication failures in the operating room: an observational classification of recurrent types and effects. *Quality and Safety in Health Care*. 2004;**13**:330-334.
85 Davenport DL, Henderson WG, Mosca CL, Khuri SF, Mentzer RM, Jr. Risk-adjusted morbidity in teaching hospitals correlates with reported levels of communication and collaboration on surgical teams but not with scale measures of teamwork climate, safety climate, or working conditions. *J Am Coll Surg*. 2007;**205**:778-784.
86 Schaefer HG, Helmreich RL. The importance of human factors in the operating room. *Anesthesiology*. 1994;**80**:479.
87 Wright D, Mackenzie SJ, Buchan I, Cairns CS, Price LE. Critical incidents in the intensive therapy unit. *Lancet*. 1991;**338**:676-678.
88 Greenberg CC, Regenbogen SE, Studdert DM, et al. Patterns of communication breakdowns resulting in injury to surgical patients. *J Am Coll Surg*. 2007;**204**:533-540.
89 Donchin Y, Gopher D, Olin M, et al. A look into the nature and causes of human errors in the intensive care unit. *Critical care medicine*. 1995;**23**:294-300.
90 Raeder T, Flin R, Cuthberson B. *Factors Affecting Team Communication in the Intensive Care Unit (ICU)*. Hampshire England Ashgate Publishing Limited; 2008.
91 Helmreich RL, Meritt AC. Culture at work in aviation and medicine: National, organizational, and professional influences. Asgate Publishing Ltd, Aldershot, England, 2001.
92 Thomas EJ, Sexton JB, Helmreich RL. Discrepant attitudes about teamwork among critical care nurses and physicians. *Critical care medicine*. 2003;**31**:956-959.
93 Makary MA, Sexton JB, Freischlag JA, et al. Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. *J Am Coll Surg*. 2006;**202**:746-752.
94 Huang DT, Clermont G, Sexton JB, et al. Perceptions of safety culture vary across the intensive care units of a single institution. *Critical care medicine*. 2007;**35**:165-176.
95 Sexton JB, Pronovost PJ, Makary MA, et al. Teamwork in the operating room: frontline perspectives among hospitals and operating room personnel. *Anesthesiology*. 2006;**105**:877-884.
96 Reader TW, Flin R, Mearns K, Cuthbertson BH. Interdisciplinary communication in the intensive care unit. *British Journal of Anaesthesia*. 2007;**98**:347-352.
97 Sluiter JK, Bos AP, Tol D, Calff M, Krijnen M, Frings-Dresen MH. Is staff well-being and communication enhanced by multidisciplinary work shift evaluations? *Intensive care medicine*. 2005;**31**:1409-1414.
98 Davenport DL, Working Conditions Surg R. Risk-adjusted morbidity in teaching hospitals correlates with reported levels of communication and collaboration on surgical teams but not with scale measures of teamwork climate, safety climate, or working conditions. *Journal of the American College of Surgeons*. 2007;**205**:778-784.
99 Measuring safety culture. *The Health Foundation Report*, London, 2011.
100 Sexton JB, Helmreich RL, Neilands TB, et al. The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research. *BMC health services research*. 2006;**6**:44-44.
101 Speroff T, Nwosu S, Greevy R, et al. Organisational culture: variation across hospitals and connection to patient safety climate. *Qual Saf Health Care*. 2010;**19**:592-596.
102 Pronovost PJ, Weast B, Holzmueller CG, et al. Evaluation of the culture of safety: survey of clinicians and managers in an academic medical center. *Qual Saf Health Care*. 2003;**12**:405-410.
103 Carney BT, West P, Neily JB, Mills PD, Bagian JP. Improving perceptions of teamwork climate with the Veterans Health Administration medical team training program. *American journal of medical quality : the official journal of the American College of Medical Quality*. 2011;**26**:480-484.

104 Sexton JB, Thomas EJ, Helmreich RL. Error, stress,and teamwork in medicine and aviation: cross sectional surveys. B*ritish Medical Journal*. 2000;**320**:745-749.

105 Reader T, Flin R, Lauche K, Cuthbertson BH. Non-technical skills in the intensive care unit. *British journal of anaesthesia*. 2006;**96**:551-559.

106 Taylor JA, Dominici F, Agnew J, Gerwin D, Morlock L, Miller MR. Do nurse and patient injuries share common antecedents? An analysis of associations with safety climate and working conditions. *BMJ Qual Saf*. 2012;**21**:101-111.

107 Haynes AB, Weiser TG, Berry WR, et al. Changes in safety attitude and relationship to decreased postoperative morbidity and mortality following implementation of a checklist-based surgical safety intervention. *BMJ Qual Saf*. 2011;**20**:102-107.

108 Wheelan SA, Burchill CN, Tilin F. The link between teamwork and patients' outcomes in intensive care units. *American journal of critical care : an official publication, American Association of Critical-Care Nurses*. 2003;**12**:527.

109 Huang DT, Clermont G, Kong L, et al. Intensive care unit safety culture and outcomes: a US multicenter study. *International journal for quality in health care : journal of the International Society for Quality in Health Care / ISQua*. 2010;**22**:151-161.

110 Timmel J, Kent PS, Holzmueller CG, Paine L, Schulick RD, Pronovost PJ. Impact of the Comprehensive Unit-based Safety Program (CUSP) on safety culture in a surgical inpatient unit. *Jt Comm J Qual Patient Saf*. 2010;**36**:252-260.

111 Lipitz-Snyderman A, Steinwachs D, Needham DM, Colantuoni E, Morlock LL, Pronovost PJ. Impact of a statewide intensive care unit quality improvement initiative on hospital mortality and length of stay: retrospective comparative analysis. *BMJ (Clinical research ed)*. 2011;**342**:d219.

112 Dudas RA, Bundy DG, Miller MR, Barone M. Can teaching medical students to investigate medication errors change their attitudes towards patient safety? *BMJ Qual Saf*. 2011;**20**:319-325.

113 Chu-Weininger MY, Wueste L, Lucke JF, Weavind L, Mazabob J, Thomas EJ. The impact of a tele-ICU on provider attitudes about teamwork and safety climate. *Qual Saf Health Care*. 2010;**19**:e39.

114 Thomas EJ, Sexton JB, Neilands TB, Frankel A, Helmreich RL. The effect of executive walk rounds on nurse safety climate attitudes: a randomized trial of clinical units[ISRCTN85147255] [corrected]. *BMC health services research*. 2005;**5**:28.

115 Cooper JB, Blum RH, Carroll JS, et al. Differences in safety climate among hospital anesthesia departments and the effect of a realistic simulation-based training program. *Anesthesia and analgesia*. 2008;**106**:574-584, table of contents.

116 Pettker CM, Thung SF, Raab CA, et al. A comprehensive obstetrics patient safety program improves safety climate and culture. *American journal of obstetrics and gynecology*. 2011;**204**:216 e211-216.

117 Norden-Hagg A, Sexton JB, Kalvemark-Sporrong S, Ring L, Kettis-Lindblad A. Assessing safety culture in pharmacies: the psychometric validation of the Safety Attitudes Questionnaire (SAQ) in a national sample of community pharmacies in Sweden. *BMC clinical pharmacology*. 2010;**10**:8.

118 Kivimäki M, Sutinen R, Elovainio M, et al. Sickness absence in hospital physicians: 2 year follow up study on determinants. *Occupational and environmental medicine*. 2001;**58**:361-366.

119 Abualrub RF, Gharaibeh HF, Bashayreh AEI. The relationships between safety climate, teamwork, and intent to stay at work among Jordanian hospital nurses. *Nursing forum*. 2012;**47**:65-75.

120 Shortell SM, Zimmerman JE, Rousseau DM, et al. The Performance of Intensive Care Units: Does Good Management Make a Difference? *Medical Care*. 1994;**32**:508-525.

121 Boyle DK, Bott MJ, Hansen HE, Woods CQ, Taunton RL. Managers' leadership and critical care nurses' intent to stay. *Am J Crit Care*. 1999;**8**:361-371.

122 Fellander-Tsai L, Westfelt P, Escher C, Hedskold M, Kjellin A. The Center for Advanced Medical Simulation, Karolinska Institutet, Karolinska University Hospital, and Stockholm County Council. *Journal of surgical education*. 2010;**67**:344-347.

123 Jackson S, Martin AJ, Eklund RC. Long and short measures of flow: the construct validity of the FSS-2. DFS-2, and new brief counterparts. *Journal of Sport and Exercise Psychology*. 2008;**30**:561-587.
124 webpage. https://med.uth.edu/chqs/products/safety-attitudes-and-safety-climate-questionnaire/. Access date 2013-04-21.
125 H B, R P. *Applied Mixed Models in Medicine*. 2nd ed John Wiley ans Sons Ltd; 2006.
126 Stokes, E M, Davies. *Categorical Data Analysis Using the SAS System*. 2nd ed. Cary, NC SAS Institute Inc; 2000.
127 Rosen MA, Salas E, Wilson KA, et al. Measuring team performance in simulation-based training: adopting best practices for healthcare. *Simulation in healthcare : journal of the Society for Simulation in Healthcare*. 2008;**3**:33-41.
128 Sandahl C, Gustafsson H, Wallin CJ, et al. Simulation team training for improved teamwork in an intensive care unit. *International Journal of Health Care Quality Assurance*. 2013;**26**.
129 Olympio MA, Whelan R, Ford RP, Saunders IC. Failure of simulation training to change residents' management of oesophageal intubation. *Br J Anaesth*. 2003;**91**:312-318.
130 Zausig YA, Grube C, Boeker-Blum T, et al. Inefficacy of simulator-based training on anaesthesiologists' non-technical skills. *Acta anaesthesiologica Scandinavica*. 2009;**53**:611-619.
131 de Fockert JW, Rees G, Frith CD, Lavie N. The Role of Working Memory in Visual Selective Attention. *Science*. 2001;**291**:1803-1806.
132 Pearce CL, Sims HP. Vertical Versus Shared Leadership as Predictors of the Effectiveness of Change Management Teams: An Examination of Aversive, Directive, Transactional, Transformational, and Empowering Leader Behaviors. *Group Dynamics: Theory, Research, and Practice*. 2002;**6**:172-197.
133 Bergman JZ, Rentsch JR, Small EE, Davenport SW, Bergman SM. The shared leadership process in decision-making teams. *J Soc Psychol*. 2012;**152**:17-42.
134 Marshall RL, Gorman PJ, Verne D, et al. Practical training for postgraduate year 1 surgery residents. *American journal of surgery*. 2000;**179**:194-196.
135 Kameg K, Howard VM, Clochesy J, Mitchell AM, Suresky JM. The impact of high fidelity human simulation on self-efficacy of communication skills. *Issues in mental health nursing*. 2010;**31**:315-315.
136 Paige JT, Kozmenko V, Yang T, et al. High-fidelity, simulation-based, interdisciplinary operating room team training at the point of care. *Surgery*. 2009;**145**:138-146.
137 Csikszentmihalyi M. *Flow: The psychology of Optimal Experience*. New York Harper and Row; 1990.
138 Harder BN, Ross CJ, Paul P. Instructor comfort level in high-fidelity simulation. *Nurse education today*. 2012.
139 Lingard L, Reznick R, Espin S, Regehr G, DeVito I. Team communications in the operating room: talk patterns, sites of tension, and implications for novices. *Academic medicine : journal of the Association of American Medical Colleges*. 2002;**77**:232-237.
140 Baggs JG, Schmitt MH, Mushlin AI, et al. Association between nurse-physician collaboration and patient outcomes in three intensive care units. *Critical care medicine*. 1999;**27**:1991-1998.
141 Hojat M, Tangucci M, Liva C, et al. Comparisons of American, Israeli, Italian and Mexican physicians and nurses on the total and factor scores of the Jefferson scale of attitudes toward physician-nurse collaborative relationships. *International journal of nursing studies*. 2003;**40**:427-435.
142 Flin R, Yule S, McKenzie L, Paterson-Brown S, Maran N. Attitudes to teamwork and safety in the operating theatre. *The surgeon : journal of the Royal Colleges of Surgeons of Edinburgh and Ireland*. 2006;**4**:145-151.
143 O'Leary KJ, Wayne DB, Haviley C, Slade ME, Lee J, Williams MV. Improving teamwork: impact of structured interdisciplinary rounds on a medical teaching unit. *Journal of general internal medicine*. 2010;**25**:826-832.

144 Khoshbin A, Lingard L, Wright JG. Evaluation of preoperative and perioperative operating room briefings at the Hospital for Sick Children. *Canadian Journal of Surgery*. 2009;**52**:309-315.
145 Warelow PJ. Nurse-doctor relationships in multidisciplinary teams: Ideal or real? *International Journal f Nursing Practice* 1996.
146 Waterson P, Griffiths P, Stride C, Murphy J, Hignett S. Psychometric properties of the Hospital Survey on Patient Safety Culture: findings from the UK. *Qual Saf Health Care*. 2010;**19**:e2.